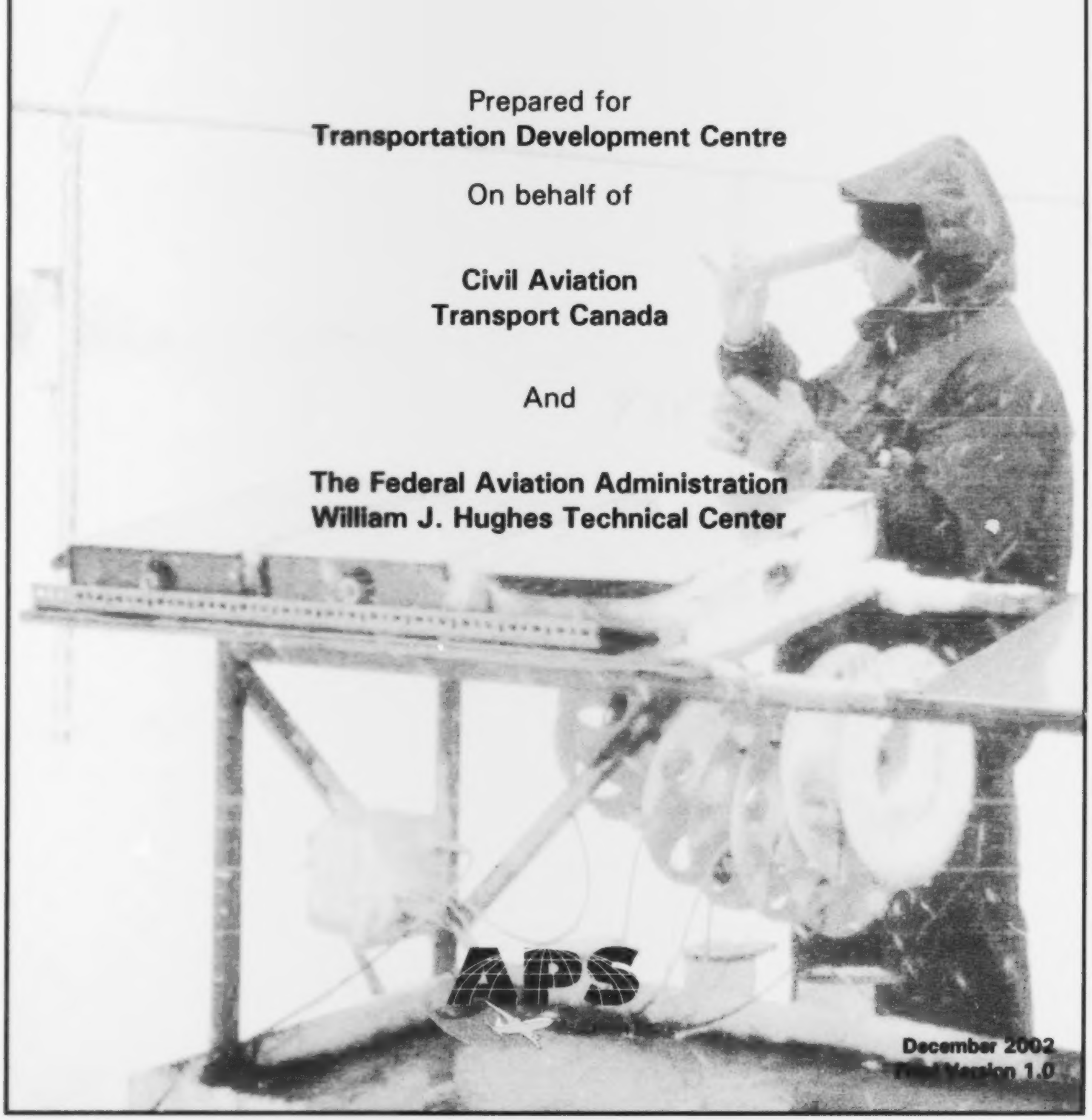
TP 13994E

Generation of Holdover Times Using the New Type I Fluid Test Protocol



Prepared for
Transportation Development Centre

On behalf of

Civil Aviation
Transport Canada

And

The Federal Aviation Administration
William J. Hughes Technical Center

APS

December 2002
Final Version 1.0

106-07437

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Generation of Holdover Times Using the New Type I Fluid Test Protocol

by

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Peter Dawson
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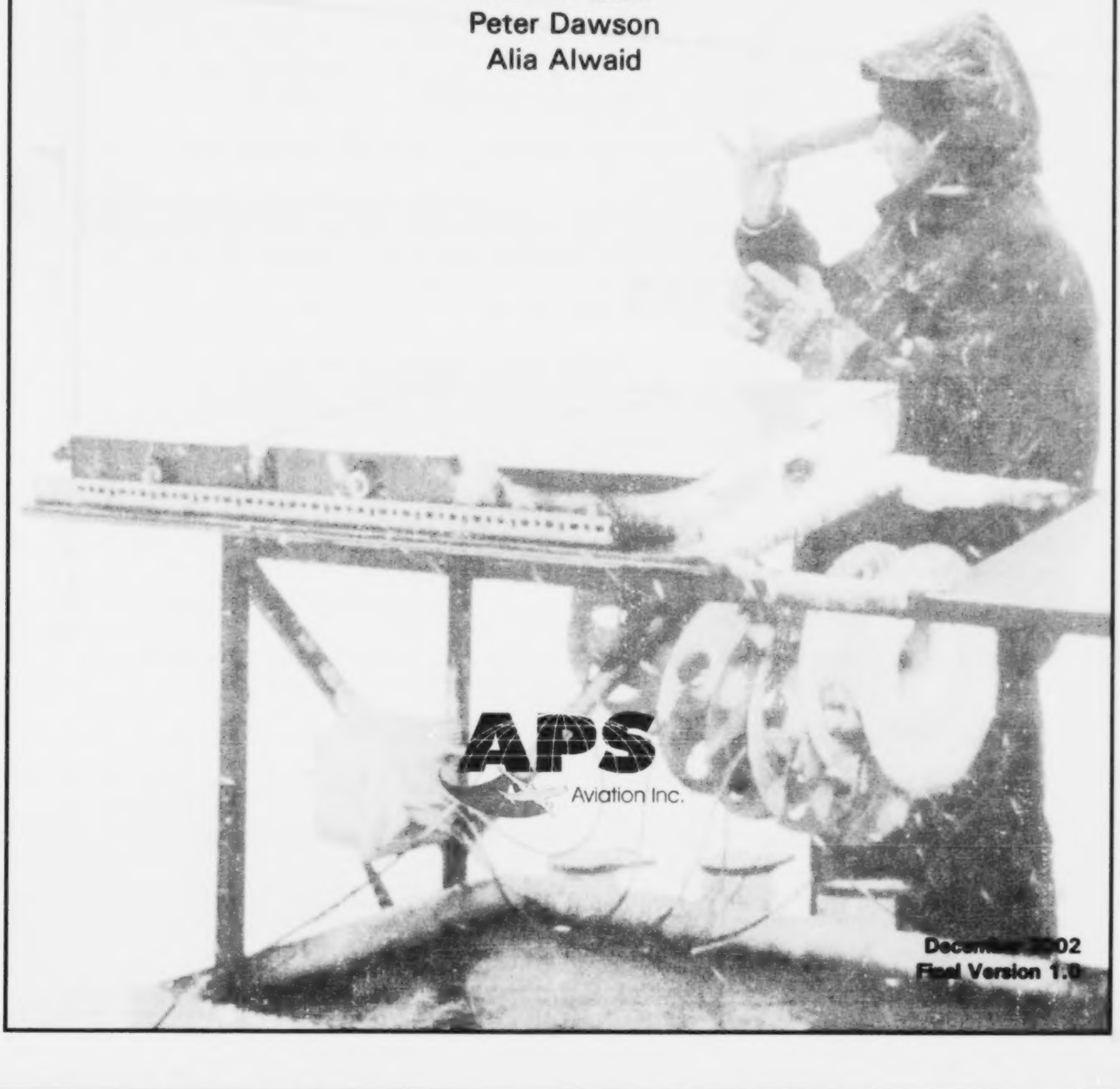

APS Aviation Inc.

December 2002
Final Version 1.0

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The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

DOCUMENT ORIGIN AND APPROVAL RECORD

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Un sommaire français se trouve avant la table des matières.

PREFACE

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for all newly qualified de/anti-icing fluids;
- To evaluate the parameters specified in Proposed SAE Aerospace Standard AS 5485 for frost endurance time tests in a laboratory;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To develop holdover times in snow using a more realistic protocol for Type I fluid endurance time testing;
- To further evaluate the flow of contaminated fluid from the wing of an aircraft during simulated takeoff runs;
- To examine the change in viscosity with the application process of Type IV fluids;
- To further evaluate hot water deicing;
- To compare endurance times in natural snow with those in artificial snow;
- To provide support for tactile tests at the Toronto Airport Central Deicing Facility;
- To utilize ice sensors for a pre-takeoff contamination check;
- To prepare the JetStar and Canadair RJ wings for thermodynamic tests; and
- To provide support services to Transport Canada.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2001-02 are documented in nine reports. The titles of the reports are as follows:

• TP 13991E	Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter;
• TP 13992E	Evaluation of Laboratory Test Parameters for Frost Endurance Time Tests;
• TP 13993E	Impact of Winter Weather on Holdover Time Table Format;
• TP 13994E	Generation of Holdover Times Using the New Type I Fluid Test Protocol;
• TP 13995E	Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid;

- TP 13996E Influence of Application Procedure on Anti-icing Fluid Viscosity;
- TP 13997E Endurance Time Tests in Snow: Reconciliation of Indoor and Outdoor Data 2000-02;
- TP 13998E Exploratory Aircraft Ground Icing Research for the 2001-02 Winter; and
- TP 13999E Three Aircraft Ground Icing Research Activities During the 2001-02 Winter.

This report, TP 13994E, has the following objectives:

- To develop holdover times in snow using a more realistic protocol for Type I fluid endurance time testing; and
- As a secondary objective, to conduct endurance time tests using the newly developed protocol with Type I fluid diluted to a standard mix (close to 50/50 glycol/water mix).

The objectives were met by conducting a series of tests in natural snow using the previously accepted wing leading-edge thermal equivalent test protocol. Tests were carried out by two testing agents during the winter of 2001-02 and provided the basis for the development of the Type I holdover time table.

ACKNOWLEDGEMENTS

This research has been funded by Transport Canada, with support from the U.S. Federal Aviation Administration, William J. Hughes Technical Center. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Civil Aviation Directorate and the Transportation Development Centre of Transport Canada, the U.S. Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada (formerly known as Atmospheric Environment Services Canada), and several fluid manufacturers. Special thanks are extended to US Airways Inc., Air Canada, American Eagle Airlines Inc., the National Center for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, Ottawa International Airport Authority, ATCO Airports, Aviation Boréale, GlobeGround North America, and Dow Chemical Company for provision of personnel and facilities, and for their co-operation with the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Nicolas Blais, Yagusha Bodnar, Alison Cairns, Robert Paris, Parimal Patel, Harvinder Rajwans, Ruth Tikkanen, Bob MacCallum, Trevor Leslie, Chris McCormack, and David Belisle.

Special thanks are extended to Frank Eyre and Barry Myers of the Transportation Development Centre for their participation in, contribution to, and guidance in the preparation of these documents.

Transport Canada Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.
TP 13994E

2. Project No.
5241-45

3. Recipient's Catalogue No.

4. Title and Subtitle
Generation of Holdover Times Using the New Type I Fluid Test Protocol

5. Publication Date
December 2002

6. Performing Organization Document No.
CM 1680

7. Author(s)
Nicoara Moc, Peter Dawson, and Alia Alwaid

8. Transport Canada File No.
2450-BP-14

9. Performing Organization Name and Address
APS Aviation Inc.
1100 René Lévesque Blvd. West
Suite 1340
Montreal, Quebec
Canada H3B 4N4

10. PWGSC File No.
MTB-2-00015

11. PWGSC or Transport Canada Contract No.
T8200-011557/001/MTB

12. Sponsoring Agency Name and Address
Transportation Development Centre (TDC)
800 René Lévesque Blvd. West
Suite 600
Montreal, Quebec
H3B 1X9

13. Type of Publication and Period Covered
Final

14. Project Officer
Barry B. Myers

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

APS Aviation Inc. (APS) undertook a study to measure the fluid endurance times of SAE Type I fluids using a newly developed protocol that takes account of the contribution of heat to more closely simulate the nature of anti-icing operations under natural snow conditions. The use of this protocol for diluted Types II and IV was also explored.

Type I

To achieve the objective of this study, a series of natural snow tests was conducted using heated SAE Type I fluid on empty aluminium box surfaces that were found to be representative of wing leading-edge surfaces. Natural snow tests using the newly developed Type I protocol were conducted by APS at Dorval Airport and by the Anti-Icing Materials International Laboratory at its facility located in Chicoutimi, Quebec. Three Type I fluid brands were tested during several snowstorms, for a total of 193 tests. The fluid was applied at a freeze point 10°C below outside air temperature.

Based on these tests, holdover time tables were produced and accepted by the industry at the SAE G-12 Holdover Time Subcommittee meeting in Frankfurt, Germany, in June 2002. The holdover time values were between the original 6 to 15 minute values and the lower values that had been adopted in May 2000.

Type II & IV

Industry members at a meeting in November 2000 suggested that the endurance time test procedure for diluted Type II and Type IV fluids should also recognize the contribution of heat and use the same box that is used for Type I fluids. Preliminary tests were conducted, and it was concluded that the heat caused significant improvements in endurance times for some fluids in some conditions. Further work is required to substantiate these findings.

17. Key Words
SAE Type I fluid holdover time, Type I protocol, natural snow, endurance time, holdover time table format, diluted Type II and IV fluids

18. Distribution Statement
Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)
Unclassified

20. Security Classification (of this page)
Unclassified

21. Declassification (date)
—

22. No. of Pages
xxii, 106, apps

23. Price
Shipping/ Handling

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada TP 13994E	2. N° de l'étude 5241-45	3. N° de catalogue du destinataire

4. Titre et sous-titre Generation of Holdover Times Using the New Type I Fluid Test Protocol	5. Date de la publication Décembre 2002
	6. N° de document de l'organisme exécutant CM 1680
7. Auteur(s) Nicoara Moc, Peter Dawson et Alia Alwaid	8. N° de dossier - Transports Canada 2450-BP-14
9. Nom et adresse de l'organisme exécutant APS Aviation Inc. 1100, boul. René-Lévesque Ouest Bureau 1340 Montréal (Québec) Canada H3B 4N4	10. N° de dossier - TPSGC MTB-2-00015
	11. N° de contrat - TPSGC ou Transports Canada T8200-011557/001/MTB
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 800, boul. René-Lévesque Ouest Bureau 600 Montréal (Québec) H3B 1X9	13. Genre de publication et période visée Final
	14. Agent de projet Barry B. Myers

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à neuf rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

APS Aviation Inc. (APS) a entrepris une étude qui visait à mesurer l'endurance des liquides de type I de la SAE à l'aide d'un protocole nouvellement élaboré qui tient compte du rôle de la chaleur et simule donc plus fidèlement les opérations de dégivrage/antigivrage dans des conditions de neige naturelle. On a aussi examiné la pertinence de ce protocole pour l'essai des liquides de type II et de type IV dilués.

Liquides de type I

Une série d'essais sous neige naturelle ont été menés à l'aide de liquides de type I de la SAE chauffés, appliqués sur des boîtes d'aluminium vides qui s'étaient avérées représentatives du bord d'attaque d'une aile. Ces essais, qui mettaient en œuvre le protocole d'essai nouvellement élaboré pour les liquides de type I, ont été menés par APS à l'Aéroport de Dorval et par le Laboratoire international des matériaux antigivre à ses installations de Chicoutimi, au Québec. Trois marques de liquide de type I ont été essayées pendant plusieurs tempêtes de neige, pour un total de 193 essais. Le liquide était appliqué à un point de congélation de 10 degrés Celsius inférieur à la température de l'air extérieur.

Ces essais ont donné lieu à des tableaux de durées d'efficacité qui ont reçu l'aval de l'industrie à la réunion du sous-comité G-12 de la SAE sur les durées d'efficacité tenue à Francfort, en Allemagne, en juin 2002. Les valeurs de ces tableaux se situaient à mi-chemin entre les anciennes valeurs de 6 à 15 minutes et les valeurs réduites, adoptées en mai 2000.

Liquides de type II et de type IV

Lors d'une réunion tenue en novembre 2000, les membres de l'industrie ont suggéré que la procédure d'essai d'endurance des liquides de type II et de type IV dilués tienne aussi compte du rôle de la chaleur et qu'elle utilise la même boîte d'aluminium qui sert aux essais de liquides de type I. Au terme d'essais préliminaires, il a été conclu que la chaleur améliorait de façon significative les valeurs d'endurance de certains liquides, dans certaines conditions. D'autres travaux s'imposent pour étayer ces résultats.

17. Mots clés Durée d'efficacité des liquides de type I de la SAE, protocole d'essai des liquides de type I, neige naturelle, endurance, format des tableaux des durées d'efficacité, liquides de type II et de type IV dilués	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication) Non classifiée	20. Classification de sécurité (de cette page) Non classifiée	21. Déclassification (date) —	22. Nombre de pages xxii, 106, ann.	23. Prix Port et manutention

EXECUTIVE SUMMARY

Introduction and Background

Under contract to the Transportation Development Centre of Transport Canada (TC), APS Aviation Inc. (APS) undertook a research program, co-sponsored by the U.S. Federal Aviation Administration (FAA), to use a new test protocol to measure natural snow endurance times of SAE Type I fluids.

From the early 1990s, the Type I fluid holdover time range for snow conditions was 6 to 15 minutes. Based on a series of SAE Type I fluid endurance time tests on flat plates conducted in the 1999-2000 winter and discussions at a SAE G-12 Holdover Time Subcommittee meeting held in Toulouse, France, in May 2000, the holdover times for snow were reduced to values significantly shorter than 6 to 15 minutes. The reduction in fluid endurance times coincided with the general realization that the test protocol was suspect.

As a result, APS was directed to develop a test protocol for measuring endurance times for SAE Type I fluids that would reflect real field operations. The ideal protocol would simulate the full nature of actual de/anti-icing operations on real wings in the natural environment. A study was carried out in the winter of 2001-01 and the findings were reported in TC Report TP 13827E, *SAE Type I Fluid Endurance Time Test Protocol*. This new protocol consisted of using a new test surface that provided a thermal equivalent to the wing leading edge. The new surface was determined to be an empty aluminum box insulated on all sides except the top. The recommended test temperature for the Type I fluid was 60°C and the recommended quantity was 0.5 L. The fluid was applied along the top edge of the test surface using a specially designed fluid spreader.

Changes to Type I Fluid Holdover Time Table Format

In addition to recommending the new outdoor test procedures in 2001, APS identified that the temperature ranges of the existing Type I holdover time (HOT) table imposed operational penalties at warmer temperatures. This led to a parallel study to carry out a survey of winter weather data and deicing operations at several airports. Based on this study, the Type I fluid holdover time table format was improved. The changes to the holdover time table format included the elimination of the "above 0°C" row, the addition of a new temperature row (above -3°C), and the addition of a column for Light Snow. These changes are described in detail in TC Report TP 13993E, *Impact of Winter Weather on Holdover Time Table Format*.

Description and Processing of Data

Natural snow tests using the newly developed Type I protocol were conducted by APS at Dorval Airport and by the Anti-Icing Materials International Laboratory (AMIL) in Chicoutimi, Quebec, during the winter of 2001-02. Fluids were applied to the surface of aluminum boxes during several snowstorms, for a total of 193 tests. The fluid was applied at a freeze point 10°C below outside air temperature (10°C buffer). Also, fluid endurance tests on standard plates using the conventional HOT procedure were conducted by APS to provide a baseline for comparison.

As a secondary objective, endurance time tests using the newly developed protocol were conducted with Type I fluid diluted to a standard mix (close to 50/50 glycol/water mix).

Results and Conclusions

Type I

Based on these tests, APS produced holdover time tables and presented them to the industry at the SAE G-12 Holdover Time Subcommittee meeting in Frankfurt, Germany, in June 2002. At the meeting, many industry members expressed their satisfaction with the quantity and quality of the data presented. The new Type I holdover time table was generally accepted by the industry, with the exception of the lower precipitation rate limit for the new "Light Snow" column. TC proposed that a lower limit of 3 g/dm^2/h be used, while the FAA selected a lower limit of 5 g/dm^2/h.

The currently accepted holdover time values in snow conditions are between the values used (6 to 15 minutes) and the lower values adopted in Toulouse in May 2000. For example, in the 0 to -10°C temperature range of the holdover time table, the values established in Toulouse were 3 to 6 minutes. Based on the data collected during the winter of 2001-02, the holdover times are 4 to 6 minutes for temperatures of -3 to -10°C, and 6 to 11 minutes for temperatures above -3°C.

The combined data set from tests conducted on empty aluminum boxes by APS and AMIL was compared with the fluid failure data points measured during full-scale tests. The full-scale test results were found to be a good representation of the box tests.

According to the endurance time test results, the standard mix fluid had, on average, an endurance time about 10 percent longer than the 10°C buffer fluid. Based on these results, a HOT table with cells that recognize variability in fluid strength (50/50 and 10°C fluid freeze point buffer) for Type I fluids was not implemented.

Type II & IV

Industry members at an SAE G-12 meeting held in Montreal in November 2000 suggested that the endurance time test procedure for Type II and Type IV fluids, at 50/50 and 75/25 concentrations, should also recognize the contribution of heat and use the same box that is used for the tests with Type I fluids. Subsequently, preliminary tests were conducted and it was concluded that heat caused a significant improvement in endurance times. Further work is required to substantiate these findings.

Recommendations

Several recommendations for future testing are made in this report, including the following:

- Conduct tests to examine whether latent heat of freezing influences Type I fluid endurance times;
- Conduct tests to document adherence times relative to endurance times during snow deicing tests with Type I fluid; and
- Examine further the suitability of using the new Type I outdoor test protocol to measure snow endurance times for heated Type II and Type IV fluids.

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SOMMAIRE

Introduction et contexte

À la demande du Centre de développement des transports de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris un programme de recherche coparrainé par la Federal Aviation Administration (FAA) des États-Unis, qui visait l'utilisation d'un nouveau protocole d'essai pour mesurer l'endurance des liquides de type I de la SAE dans des conditions de neige naturelle.

Depuis le début des années 1990, la plage des durées d'efficacité des liquides de type I dans des conditions de neige variait de 6 à 15 minutes. Mais à la lumière d'une série d'essais d'endurance de liquides de type I de la SAE menés sur des plaques planes au cours de l'hiver 1999-2000, et par suite de discussions tenues à une réunion du sous-comité G-12 de la SAE sur les durées d'efficacité, qui a eu lieu à Toulouse, en France, en mai 2000, les durées d'efficacité pour la neige ont été considérablement réduites par rapport à ces plages de 6 à 15 minutes. La réduction de ces valeurs d'endurance s'est accompagnée d'une suspicion générale à l'égard du protocole d'essai.

C'est ainsi qu'APS a reçu le mandat d'élaborer un protocole d'essai pour mesurer l'endurance des liquides de type I de la SAE, lequel devrait reproduire les conditions de service réel. De fait, le protocole idéal serait celui qui simulerait parfaitement les opérations de dégivrage/antigivrage menées sur de vraies ailes, dans un environnement naturel. Une étude a été menée au cours de l'hiver 2000-2001 et les résultats ont fait l'objet du rapport TP 13827E de TC, intitulé *SAE Type I Fluid Endurance Time Test Protocol*. Le nouveau protocole utilisait une nouvelle surface d'essai, conçue pour offrir un équivalent thermique du bord d'attaque d'une aile. Cette surface était une boîte d'aluminium vide isolée sur toutes ses faces, sauf le dessus. La température d'essai recommandée pour le liquide de type I était 60 °C et la quantité de liquide recommandée, 0,5 L. Le liquide était appliqué sur le pourtour de la face supérieure de la boîte d'aluminium au moyen d'un applicateur spécial.

Modification du format des tableaux des durées d'efficacité des liquides de type I

Outre les nouvelles procédures recommandées pour les essais extérieurs en 2001, APS a constaté que les plages de températures des tableaux de durées d'efficacité existants des liquides de type I menaient à une sous-estimation néfaste aux opérations, aux températures élevées. Une étude parallèle a donc été entreprise, qui consistait en un relevé des données météorologiques hivernales et des opérations de dégivrage à plusieurs aéroports. Par suite de cette étude, le format du tableau des durées d'efficacité des liquides de type I a été amélioré. Ainsi, la ligne «au-dessus de 0 °C» a été éliminée et une nouvelle rangée de températures (au-dessus de -3 °C) a été ajoutée, ainsi qu'une nouvelle colonne pour la neige légère. Ces changements sont décrits en détail dans le rapport TP 13993E de TC, *Impact of Winter Weather on Holdover Time Table Format.*

Description et traitement des données

Des essais sous neige naturelle, faisant appel au nouveau protocole pour liquides de type I, ont été menés par APS à l'Aéroport de Dorval et par le Laboratoire international des matériaux antigivre (LIMA) à Chicoutimi, au Québec, au cours de l'hiver 2001-2002. Les liquides ont été appliqués sur des boîtes d'aluminium pendant plusieurs tempêtes de neige, pour un total de 193 essais. Le fluide était appliqué à un point de congélation de 10 degrés Celsius inférieur à la température de l'air extérieur (marge de sécurité contre le gel de 10 °C). Des essais d'endurance sur plaques planes à l'aide de la procédure d'essai classique ont aussi été effectués par APS, afin d'avoir une base de comparaison.

Au titre d'un objectif secondaire, les essais d'endurance faisant appel au nouveau protocole ont été menés avec un mélange standard de liquide de type I dilué (mélange 50/50 d'eau et de glycol).

Résultats et conclusions

Liquides de type I

À partir des résultats des essais, APS a produit de nouveaux tableaux des durées d'efficacité et les a présentés à l'industrie, lors de la réunion du comité G-12 sur les durées d'efficacité de la SAE, qui a eu lieu à Francfort, en Allemagne, en juin 2002. De nombreux membres de l'industrie présents à cette réunion se sont dits satisfaits de la quantité et de la qualité des données présentées. Le nouveau tableau des durées d'efficacité des liquides de type I a reçu un accueil généralement favorable de l'industrie, si ce n'est de l'abaissement de la limite du taux de précipitations pour la nouvelle colonne «Neige légère». TC a proposé d'abaisser ce taux à 3 g/dm^2/h, tandis que la FAA optait plutôt pour un taux de 5 g/dm^2/h.

Les durées d'efficacité présentement acceptées pour des conditions de neige se situent entre les anciennes valeurs (6 à 15 minutes) et les valeurs réduites adoptées à Toulouse en mai 2000. Par exemple, dans la plage de températures de 0 à -10 °C du tableau, les valeurs établies à Toulouse étaient de 3 à 6 minutes. D'après les données recueillies à l'hiver 2001-2002, les durées d'efficacité sont de 4 à 6 minutes pour des températures de -3 à -10 °C, et de 6 à 11 minutes pour des températures au-dessus de -3 °C.

Les ensembles de données provenant des essais effectués sur des boîtes d'aluminium vides par APS et AMIL ont été combinés et comparés aux données sur la perte d'efficacité obtenues lors d'essais en vraie grandeur. Une concordance raisonnable a été constatée entre les résultats d'essais en vraie grandeur et ceux d'essais sur des boîtes d'aluminium.

D'après les résultats des essais d'endurance, le liquide préparé selon un mélange standard avait, en moyenne, une endurance supérieure d'environ 10 p. 100 à celle du liquide offrant une marge de sécurité de 10 degrés Celsius. C'est pourquoi il a été décidé de ne pas produire de tableau de durées d'efficacité des liquides de type I comportant des cellules pour des concentrations de liquide variables (50/50 et concentration offrant une marge de sécurité de 10 degrés Celsius contre le gel).

Liquides de type II et de type IV

Au cours d'une réunion du sous-comité G-12 de la SAE tenue à Montréal en novembre 2000, les membres de l'industrie ont exprimé l'opinion que la procédure d'essai pour la mesure de l'endurance des liquides de type II et de type IV, à des concentrations de 50/50 et de 75/25, devrait également tenir compte du rôle de la chaleur et recourir à la même boîte d'aluminium que les essais de liquides de type I. Au terme d'essais préliminaires, il a été conclu que la chaleur améliorait de façon significative l'endurance. D'autres travaux s'imposent pour étayer ces résultats.

Recommandations

Le rapport contient plusieurs recommandations concernant les essais futurs. En voici quelques-unes :

- mener des essais pour examiner si la chaleur latente libérée lors du gel influence l'endurance des liquides de type I;
- mener des essais pour documenter le rapport entre la durée d'adhérence et l'endurance au cours d'essais de dégivrage à l'aide de liquides de type I dans des conditions neigeuses;
- continuer d'examiner s'il est pertinent d'utiliser le nouveau protocole d'essai extérieur des liquides de type I pour mesurer l'endurance des liquides de type II et de type IV chauffés.

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GLOSSARY

AEA	Association of European Airlines
AMIL	Anti-Icing Materials International Laboratory
AMS	Aerospace Material Specifications
APS	APS Aviation Inc.
CEF	Climatic Engineering Facility
CRDA	Cooperative Research and Development Agreement
ET	Endurance Time
FAA	Federal Aviation Administration (U.S.)
FFP	Fluid Freezing Point
HOT	Holdover Time
NCAR	National Center for Atmospheric Research (U.S.)
NRC	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers
TC	Transport Canada
TDC	Transportation Development Centre

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1

1. INTRODUCTION

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC) and in collaboration with the U.S. Federal Aviation Administration (FAA), APS Aviation Inc. (APS) performed further research associated with a program started in the winter of 2000-01 to develop a protocol for measuring fluid holdover times of SAE Type I fluids.

1.1 Background

For several years, the Type I fluid holdover time range for snow conditions was 6 to 15 minutes. These values were initially based on operational experience and were substantiated in tests conducted in the early 1990s. In the winter of 1999-2000, a series of endurance time tests was conducted on the Society of Automotive Engineers (SAE) Type I fluids using test parameters developed to test Type II and IV fluids. The results of these tests were presented at the annual meeting of the SAE G-12 Holdover Time (HOT) Subcommittee held in Toulouse, France, in May 2000. At this meeting, it was recommended that holdover times for snow be reduced to values significantly shorter than those previously published. The historical (prior to 2000) holdover times are given in Figure 1.1. At a precipitation rate of 10 g/dm²/h (lower limit for moderate snowfall), the fluid time was reduced from 15 minutes to 6 minutes; at a rate of 25 g/dm²/h (upper limit for moderate snowfall), the time was reduced from 6 minutes to 3 minutes.

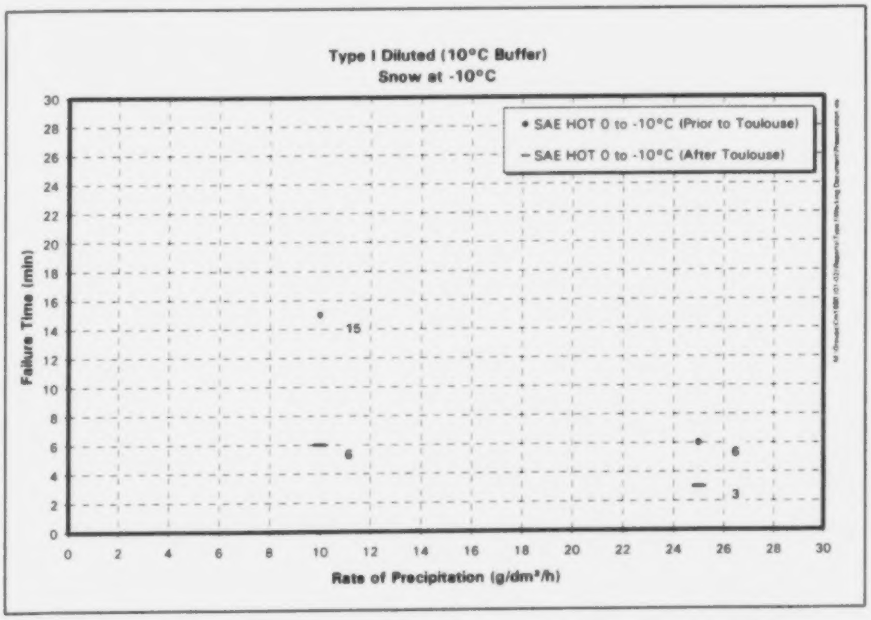

Figure 1.1: Effect of Precipitation on Endurance Time

The reduction in fluid holdover times led to concerned discussion at industry meetings and to the general realization that the test protocol may be faulty. It was generally believed that the reduction in holdover times resulted from test protocol, which failed to take into account the contribution of the heat transfer from the heated fluid to the wing surface.

Consequently, APS was asked to develop a Type I fluid test protocol. Specifically, the objective was to develop a test protocol to measure endurance times for SAE Type I fluids that would reflect real field operations. The ideal protocol would simulate the full nature of actual de/anti-icing operations on aircraft wings in the natural environment.

Research led to the conclusion that two test procedures were required: one for outdoor tests in natural precipitation and wind conditions, and a procedure for laboratory tests in calm conditions.

The following procedures were recommended:

a) Test Procedure for Outdoor Tests:

- Use a new test surface that provides a thermal equivalent to wing leading edges. This test surface is intended to produce an accurate representation of the temperature decay rate demonstrated by wings following application of heated deicing fluid in natural outdoor conditions;
- Heat Type I fluid to recommended test temperature of 60°C, with an acceptance range of +2°C and 0°C;
- Use recommended quantity of 0.5 L of Type I fluid ; and
- Ensure fluid application process consists of the following steps:
    - Clean contamination from the surface;
    - Wet the surface with a small amount of fluid at Outside Air Temperature (OAT) prior to application of the test fluid; and
    - Apply the test fluid with a fluid spreader positioned along the top edge of the test surface.

b) Test Procedure for Laboratory Tests:

- In calm conditions in a laboratory, follow the existing SAE Type I fluid endurance test procedure using an unpainted aluminum plate with dimensions 0.32 x 30 x 50 cm. This provides a reasonably accurate representation of the temperature decay rate experienced by wings in natural outdoor conditions;

- Heat Type I fluid to recommended test fluid temperature of 20°C, with an acceptance range of +2°C and 0°C;
- Use recommended quantity of 1.0 L of Type I fluid; and
- Follow the same method of applying fluid as that described for outdoor tests.

The study and recommendations were reported in TC report TP 13827E, *SAE Type I Fluid Endurance Time Test Protocol* (1). The activities were undertaken to develop the new protocol to form the basis of this report and are discussed later in this section.

In addition to recommending the preceding test procedures, the report identified that the temperature range format of the existing HOT table imposed operational penalties at warmer temperatures. Holdover times throughout the temperature range are based on the lower temperature limit. A temperature range with -3°C as its lower limit would have much longer holdover times then one with -10°C as its lower limit. As well, a finer split would serve to provide a better representation of snowfall events. In the existing table, the temperature range of 0 to -10°C encompassed 70 percent of all snowfall events. It was recommended that a temperature range having -3°C as its lower limit be considered for incorporation into the HOT tables.

To support a change to the format of the HOT table, a survey of winter operations was conducted at a number of selected airports worldwide. Results of this survey were compared to the existing temperature limits of the HOT table to illustrate how the frequency of deicing events is distributed by temperature range for each precipitation type.

Type I fluid endurance time tests in natural snow conditions using the new protocol were conducted during the winter of 2001-02. These tests were conducted over a range of temperatures, and the resulting data enabled the development of a HOT table cell at a temperature range above -3°C for snow. These tests are discussed in Section 4 of this report.

Type I fluid endurance testing for other precipitation conditions (freezing fog, drizzle, and rain) had historically been conducted in a laboratory, and the only temperatures tested to date had been at the lower limits of the existing temperature ranges (-10°C and -25°C). In order to produce HOT values for those precipitation conditions at a range above -3°C, supplementary testing at -3°C is necessary.

An additional demand for laboratory testing arose when the FAA identified a preference that Type I fluid endurance tests in the laboratory be conducted with fluid heated to 60°C, and that the new test surface (thermal equivalent to wing leading edge) be incorporated in the new outdoor Type I fluid test protocol. This preference led to a series of laboratory tests in an attempt to produce surface temperature profiles on the new surface (in a no-wind laboratory condition) matching those produced outdoors in a wind condition. These activities are discussed in Section 2.

The new test surface is referred to as the "empty aluminum box" throughout this report.

1.2 Objective

The objectives addressed in this report include:

a) Finalizing the new Type I test protocol;

b) Providing support to industry activities defining the fluid endurance test standard for Type I fluids;

c) Examining results from FAA tests with American Eagle;

d) Conducting Type I fluid endurance tests in natural snow conditions;

e) Examining endurance time results and comparing these to results documented from full-scale aircraft tests;

f) Making recommendations on endurance times to industry;

g) Developing test procedures and testing to ascertain whether the Type I HOT Table format should reflect:

  - Fluid at standard (50/50) strength as well as at a 10°C buffer
  - Fluid at a temperature of 60°C, as well as a lower temperature
  - Splits for additional precipitation rates such as 5 $g/dm^2/h$
  - Splits for additional temperature breaks such as -3°C; and

h) Making recommendations to industry for changes to the Type I HOT Table based on test results.

This study formed part of the 2001-03 winter research program on deicing. The work related to the Type I test protocol was commenced in the 2000-01 winter and continued according to the excerpt from the project description in the work statement for APS Aviation, which can be found in Appendix A. The work related to the Type I HOT Table format can also be found in Appendix A.

2

2. TYPE I FLUID ENDURANCE TEST PROTOCOL IN A LABORATORY ENVIRONMENT

When the development of the new test protocol for Type I fluid endurance outdoor tests was nearing completion, the FAA, co-sponsors of the study along with Transport Canada, stated a strong preference that the same protocol be used for SAE Type I fluid endurance tests in the laboratory. This would involve application of fluid at 60°C, using the new outdoor test surface (thermal equivalent to wing leading edge) referred to as the "empty aluminum box." Previously, the study team had recommended that indoor tests continue to use the existing SAE Type I fluid endurance test procedure, which involves application of fluid at 20°C on the standard aluminum test plate.

To respond to the FAA preference, a series of laboratory tests was conducted to examine the suitability of applying the outdoor test procedure in a laboratory environment. These tests consisted primarily of attempts to produce surface temperature profiles on the new outdoor test surface in a no-wind laboratory condition that would match the generic temperature profile determined for wing leading edges, measured in various wind conditions.

The examination eventually concluded that the outdoor test protocol was unsuitable for indoor tests and resulted in a decision to retain the current test procedure based on standard flat test plates. The intent of this section is to document the nature of the examination and the test results that led to that conclusion.

The issue of clarity when discussing fluid failure is significant. In order for all parties to arrive at a common point, Section 2.1 Icing Definitions has been included. These definitions are taken directly from TC report TP 13832E, *Aircraft Anti-Icing Fluid Endurance, Holdover, and Failure Times Under Winter Precipitation Conditions: A Glossary of Terms* (2).

2.1 Icing Definitions

Fluid failure

Two major forms of failure are currently in use: visual failure and adhesion failure.

Visual failure

A layer of ice crystals is plainly visible at the surface and the layer is building up thickness as precipitation continues. Generally, in the case of Type II, III, and IV fluids, uncontaminated fluid is in contact with the supporting surface at this time and therefore the ice crystal layer is not in contact with that surface and is not adhering to it. The growth of crystals in the fluid is compounded by incoming precipitation, resulting in an increased accumulation of crystals on the surface and thus in a visibly contaminated surface. When this area is large enough to be seen by an observer, a visual failure is adjudged. Obviously, the distance of the observer from the surface will influence what can be seen. For a test technician observing a plate from inches away, visual failure is characterized as a loss of gloss or obscuration of the surface by ice or slush affecting one third of a standard test plate surface. For an aircrew member viewing a wing through a window at night at a distance of several feet, only slush or bridging snow covering about one third of a critical area such as an aileron or a leading edge will be visible. Visual failure on test plates is the mode used to establish endurance times and thus holdover times.

Adhesion/Adherence failure

The failure of the fluid to perform as an anti-icing fluid. A layer of ice crystals builds up, the crystals come in contact with the surface below, and they are bonded to it.

Failure adhesion

The initial bonding of ice crystals in a fluid to the surface resulting from the diluted fluid freezing point rising above the surface temperature at a nucleation site on the surface.

Fluid adhesion

Viscosity and surface tension forces, along with a possible matrix of ice crystals in the fluid layer, impede the fluid's movement under shear and represent the effective adhesion of the fluid to the surface, resisting its removal.

Nucleation site

The site at which an ice crystal is stimulated to form from supercooled water.

First failure/First icing event

At surface discontinuities, such as gaps, and at the edges of surfaces, the fluid is at its thinnest. The first ice crystals form at such locations, known as nucleation sites. Generally the areas of ice crystal coverage grow from these locations. Depending on the thoroughness of the de/anti-icing process, first failure may occur very quickly.

Standard test plate

The standard test plate, for the purpose of this document, is restricted to the plate used in endurance time testing. It is an aluminum alloy plate 50 cm (20 in.) long and 30 cm (12 in.) wide adopted by SAE for the evaluation and certification of de/anti-icing fluid performance. For testing it is mounted at 10° to the horizontal. Along the top and two sides a line is marked 2.5 cm (1 in.)

from the edge; ice crystals commencing in these zones are ignored as outside the test area. The bottom edge is a special case because the fluid is held back and is excessively thick there. The test area of the test plate is about 75 percent of the total area. The plate is marked with horizontal lines parallel to the top edge at 7.5 cm (3 in.), 15 cm (6 in.), 22.5 cm (9 in.), 30 cm (12 in.), and 37.5 cm (15 in.). On each of these lines are marked three cross hairs, one in the middle of the line and the other two evenly spaced 7.5 cm (3 in.) each side of it for a total of 15 cross-hair sites.

Standard plate failure/plate failure

Failure is established as a visual failure of one third of the test surface based on the observation of conditions on full-scale aircraft. This usually occurs when the failure front on the plate crosses the 15 cm (6 in.) line. However, in outside snow tests, because there is usually wind, the start point may be anywhere on the plate and the progression in any direction. Under these conditions, visual failure may be estimated. Alternatively, when contamination is visible on 5 of the 15 cross hairs, the plate is determined to be one-third covered and therefore visually failed.

Complete/Total/Full/Entire plate failure

100 percent of the plate has reached a visual failure condition.

Protection time

The period that an anti-icing treatment protects aerodynamically critical surfaces from the adhesion of contamination and the resulting roughness that could cause a premature stall or result in loss of control and prevent the crew from safely operating the aircraft.

Endurance time

The time from initial application of anti-icing fluid to a standard test plate to the moment of the standard plate failure for a specific test condition simulating a weather condition.

Holdover time

The time from initial application of anti-icing fluid onto an aircraft to the moment the fluid can no longer be guaranteed to provide protection at the anticipated takeoff time. These times must be at least five minutes less than the protection time, and may be substantially less.

Holdover time guidelines

Guidelines for holdover times as a function of specific weather conditions established by the SAE G-12 holdover time committee and based on endurance time test results.

2.2 Examination of Fluid Quantities for Laboratory Tests – September 13, 2001

The initial request to examine the laboratory procedure primarily addressed the fluid temperature. The objective of the test was to examine the use of Type I fluid heated to 60°C, and to determine what other test parameters (fluid quantity, rate of fluid application, plate thickness) would need to be changed in order to produce the desired surface temperature decay.

2.2.1 Test Procedure

The procedure for the test is included as Appendix B. The test consisted of several steps:

a) Applying the appropriate quantity of fluid at the designated temperature, and using the predetermined application method on each surface, using fluid spreaders warmed to the temperature of the test fluid;

b) Monitoring and logging test surface temperatures until the temperature decayed to within 10 percent of original OAT;

c) Recording ambient temperature at the stand location;

d) Following each test set or, as needed, developing temperature decay profile charts for each tested condition, including the generic wing profile as reference; and

e) Comparing temperature profiles to generic wing profile to see whether a good match was produced.

2.2.2 Results and Conclusions

Tests were conducted on September 13, 2001, at the Climatic Engineering Facility (CEF) of National Research Council Canada (NRC) in Ottawa in conjunction with a series of tests for which the laboratory had already been booked.

Using the new outdoor protocol to generate a surface temperature decay in the laboratory that matched the generic wing mean temperature decay rate was unsuccessful for various reasons:

a) Use of thin plates failed to produce the desired temperature profile regardless of the variations in fluid application. The initial temperature was too high, and the cooling rate too rapid;

b) The standard flat plate (with a standard thickness) and varying fluid quantities and application rates with a fluid temperature at 60°C did not produce the right shape of curve; and

c) The standard flat plate (with a standard thickness), and keeping the fluid quantity at 1.0 L at 20°C, but applying the fluid with a spreader versus pouring, generated a temperature curve that better matched the wing curve. Applying 1.0 L at 60°C generated a curve well above the wing curve.

2.2.3 Recommendations

An interim report with temperature profile charts for the various tests was distributed to TC and the FAA, and is included as Appendix C.

For laboratory tests to evaluate Type I fluid endurance times, the best solution was to use the current HOT procedure that specified 1.0 L of fluid at 20°C, altered to apply fluid with the spreader. It was thought that this might be further refined to produce a closer match to the generic wing through either of two approaches:

a) It was estimated that a 5°C increase in fluid temperature (1.0 L at 25°C with spreader) would give a closer match; and

b) Alternately, a small decrease to the spreader rate of delivery might suffice.

Because the booked tests required the laboratory conditions to be changed, there was not enough time available at a constant ambient laboratory temperature to explore these options.

2.3 Determination of Empty Aluminum Box and Heated Fluid Parameters for Laboratory Tests – December 4, 2001

In the tests conducted in September, several versions of the standard aluminum test plate were used as a test surface for the laboratory test method. The FAA requested that APS examine the use of fluid heated to 60°C in combination with an empty aluminum box as a test surface, and these tests were conducted on December 4, 2001.

2.3.1 Procedure

The objective was to identify which changes to other test parameters are needed to cause this combination of fluid temperature and surface type to produce a temperature profile that matches the profile for the wing leading edge in outdoor conditions with natural wind.

The test procedure and log of the tests conducted is included in Appendix D. As in the test conducted in September, this test consisted of:

a) Applying the appropriate quantity of fluid at the designated temperature using the predetermined application method on each surface, using fluid spreaders warmed to the temperature of the test fluid;

b) Monitoring and logging the surface temperature until the temperature decayed to within 10 percent of original (OAT);

c) Recording ambient temperature at the stand location;

d) Following each test set or, as needed, developing temperature decay profile charts for each tested condition, including the generic wing profile as reference; and

e) Comparing temperature profiles to generic wing profile to see whether a good match was produced.

The variables examined included combinations of the following parameters:

a) Type of surface;

- Plate 3.2 mm thick;
- Empty aluminum box 7.5 cm, insulated;
- Empty aluminum box 7.5 cm, no insulation; and
- Empty aluminum box 7.5 cm, insulated, 4.8 mm surface.

b) Contents of aluminum box;

- Empty;
- Empty, but with fan attached to blow cold air through cavity;
- 50 percent filled with fluid at ambient temperature; and
- 100 percent filled with fluid at ambient temperature.

c) Quantity of fluid applied; and

d) Application rate, by varying the number of holes in the fluid spreader.

2.3.2 Results and Conclusions

Tests were conducted at PMG Laboratories in Blainville, Quebec. Although several days were reserved, tests were completed in one day on December 4, 2001.

Tests were run at only one air temperature, -10°C.

First a cross section of test conditions was selected from the test plan to gain a quick appreciation of the impact of the various parameters. Test conditions that were easier to work with and thus more desirable for ongoing testing were tested first. As each test session was completed, the results were entered into an Excel spreadsheet and displayed in chart form. The chart compared temperature profiles derived from test results to the temperature profile of the generic wing leading edge.

Six separate test sets, each consisting of variations on test parameters, were conducted.

The charts illustrating the temperature profiles resulting from each of the six runs are included in Appendix D.

Also included in Appendix D is a log of all the tests conducted, differentiated by variation of the test surface, fluid temperature, quantity of fluid applied, application method, and ambient temperature, as well as by test set. One test condition, Variation 8 in the *Log of Tests Conducted* and on the temperature profile charts in Appendix D, generated a temperature profile that was a good match to the wing leading edge temperature profile. This condition consisted of an empty, insulated 7.5 cm aluminum box treated with 0.25 L of fluid at 60°C and applied with the spreader using all 24 drain holes (a faster rate than for the outdoor tests, which used only 12 drain holes). Three test sets were conducted with this condition, and results demonstrated reproducibility.

Variation 1 represented the existing HOT procedure: 1 L of fluid at 20°C was poured on a standard aluminum test plate (0.32 x 30 x 50 cm).

A number of potential but less desirable solutions were not tested, as a satisfactory and more desirable solution had been identified.

2.3.3 Recommendation

For the Type I fluid endurance test conducted in the laboratory, the use of an empty insulated 7.5 cm aluminum box treated with 0.25 L of fluid at 60°C applied with the spreader using all 24 drain holes was recommended.

2.4 Determination of Type I Fluid Endurance Times Using a New Indoor Test Protocol – December 17-19, 2001

Once the decision was made to consider restructuring the HOT table format to include a temperature range above -3°C, it became necessary to develop fluid endurance times for the various types of precipitation at that temperature. The various types of precipitation required testing in the laboratory with the exception of snow, which had been tested in outdoor natural snow conditions.

The objective of these tests was to develop endurance times for SAE Type I fluid over the full range of HOT table conditions using the newly developed (PMG) test protocol described in Subsection 2.3.3.

2.4.1 Procedure

Tests were conducted at the NRC CEF during the week of December 17, 2001. A copy of the test procedure is included in Appendix E.

Endurance times were tested using the standard operating mix at 50/50 concentration and fluids mixed to a freeze point 10°C below ambient temperature.

To provide a baseline for comparison, fluid endurance tests were conducted on standard plates using the conventional HOT procedure, as well as on the surface of empty aluminum boxes.

As a supplementary objective, fluid dilution rates were measured. These tests were conducted on an empty aluminum box filled with warm (+5°C) fluid to allow for the measurement of fluid concentration until it was completely diluted and without interruption due to freezing.

Also, surface temperatures were recorded with thermistor loggers on one empty aluminum box and one plate, using the same fluids as in the endurance time tests.

The resulting plate/box temperature profiles were subsequently charted against fluid freeze point profiles. This provided an indication of the duration until fluid freezing would be expected to occur (when the temperature of the surface matched the fluid freeze point).

2.4.2 Results and Conclusions

A log of the completed tests is provided in Appendix E. The fluid endurance time resulting from each test condition is given in the column named *Fail time* and is also entered on a chart representing the HOT table (Table E-1).

The endurance time values obtained using the new test procedure were different from those expected.

The main problems occurred at the test temperature of -3°C. At this temperature, for all precipitation types in tests using the new "empty aluminum box" procedure, the fluid endurance times measured were longer than times obtained using the standard HOT procedure. The results were quite scattered. In some cases, the endurance time at the high precipitation rate was longer than at the low rate. Standard plate failures were difficult to call as ice formed in random feathery patches on the plate surface, and water collected between the patches. The ice patches were well-adhered to the surface.

Examination of the surface temperature and fluid freeze point temperature profiles casts some light on the problems encountered. An example is shown in Figure 2.1, which gives the temperature profiles for the test condition *freezing drizzle (ZD) at -3°C* and a *precipitation rate of 13 g/dm^2/h*.

The empty insulated 7.5 cm aluminum box was treated with 0.25 L of fluid at 60°C applied with the spreader using all 24 drain holes. The standard plate was treated using the conventional HOT procedure: 1.0 L of fluid at 20°C.

Compared to the standard test plate, the box surface reached a higher temperature at time of fluid application and took longer to cool to 0°C. The fluid mix had been completely diluted to the equivalent of water (fluid freeze point of 0°C) well before the box temperature reached the freeze point.

2.4.3 Recommendation

The results were reviewed with representatives from TC and the FAA to decide upon further action.

It was believed that the failure of the test surfaces to cool to ambient temperature was caused by the temperature of the artificial precipitation when sprayed from the nozzle which was a few degrees above 0°C to prevent the nozzle from freezing. The short fall-time from the nozzle to the test plate may have been insufficient to allow super-cooling of the drops. Heat transfer from the drops to surface influenced the slow cooling rate of the test surface.

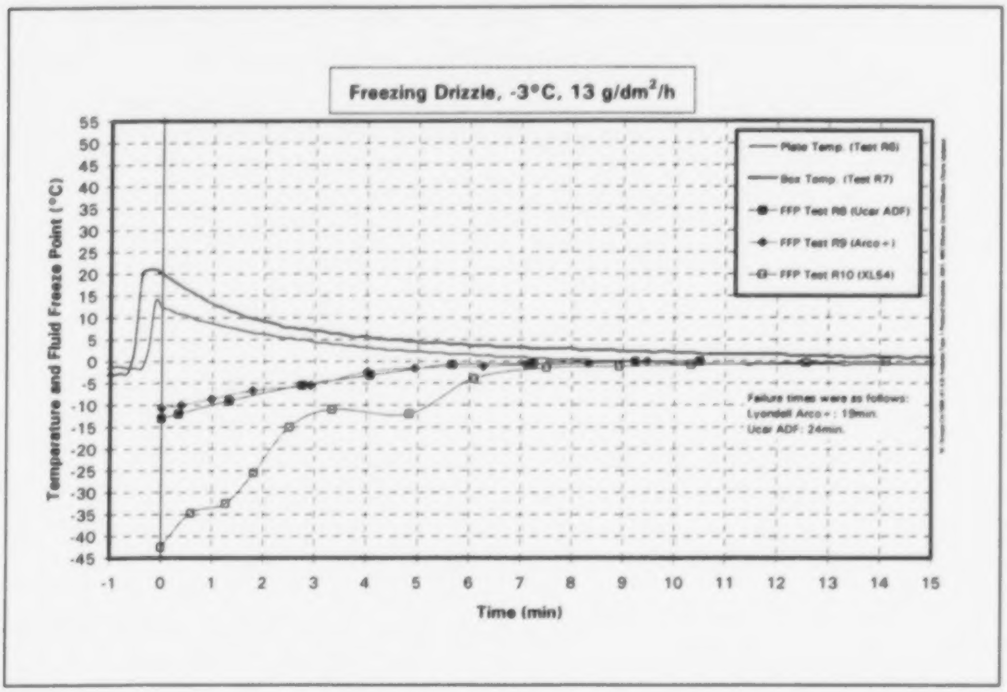

Figure 2.1: Surface Temperature Profiles and Fluid Dilution

To counteract this effect in future tests, it was decided to lower the ambient air temperature by varying amounts in a trial-and-error process, until the required temperature was reached on the test surface while it was exposed to the specified precipitation condition.

It was decided that further tests were necessary and these are described in the next section.

2.5 Determination of Type I Fluid Endurance Times Using the New Indoor Test Protocol – March 11-15, 2002

During the Type I fluid endurance tests conducted in December 2001, the test surfaces, when exposed to the artificial freezing precipitation, settled at a temperature higher than the ambient chamber temperature. It was thought that this was due to heat transfer from the drops of precipitation (hitting the test surfaces), which had insufficient time during their descent from the nozzle to cool from their initial value (2 to 3°C). In natural conditions, freezing rain or drizzle droplets are super-cooled to temperatures close to ambient, and thus do not transfer heat to the surface.

Since the higher test surface temperature caused by the warmer droplets influenced the fluid endurance times, the tests were repeated using a procedure that produced the desired test surface temperature.

The method proposed for lowering the test surface temperature to that specified by test parameters was to cool the surrounding air beyond that temperature. Heat transfer with the colder air would then cause the droplet temperatures to cool to a value where their contact with the test surface would produce the desired surface temperature.

The ambient air temperature needed to produce the desired result was expected to be different for each combination of specified test conditions (OAT, type of freezing precipitation, and precipitation rate). Each combination required separate examination and calibration.

The examination of each combination involved a series of iterative runs to determine the temperature of the surrounding air needed to produce the desired surface temperature.

Because the standard test plate has different thermal properties than the empty aluminum box surface, only the empty aluminum box was used for the calibration.

The test procedure involved two steps. First it was necessary to determine the ambient chamber temperature needed to produce the specified box surface temperature. Next, the fluid endurance tests were conducted.

2.5.1 Chamber Calibration Procedure

The test stand was placed in the normal position for testing in the specific freezing precipitation condition.

The chamber ambient temperature was set at a value below the test specification, using guidelines based on results from previous tests. Freezing precipitation was set to fall on the stand at the rate required. The precipitation was run continuously through the calibration process (without parking the sprayer) to maintain a stable condition over the stand.

Empty aluminum boxes were covered to protect them from the precipitation. Thermistor probes were installed and mounted on the stand. In accordance with the initial procedure, the plates were then treated with a Type IV fluid at the appropriate temperature to prevent ice from forming. The surface was then uncovered and exposed to the precipitation. This procedure was modified to include box surfaces treated with Type I fluid also applied at the required temperature. The Type I fluid tended to freeze within minutes, but lasted long enough to demonstrate a stabilized temperature.

In cases where the surface temperature failed to stabilize at the desired test temperature, the chamber ambient temperature was adjusted and the test repeated. This iterative process was continued until a chamber ambient temperature was established where the box surface temperature stabilized at the intended test temperature.

For example, in the calibration exercise for light freezing rain at a rate of 13 g/dm^2/h and temperature of -10°C, it was hypothesized from the pre-test assessment that an ambient temperature of -24°C would be needed to obtain a surface temperature of -10°C. In actual practice, this ambient temperature produced a surface temperature of -18°C. Through several iterations, it was determined that an ambient temperature of -11.3°C produced a surface temperature of -10°C.

2.5.2 Fluid Endurance Test Procedure

Tests were conducted at NRC CEF during the week of March 11, 2002. A copy of the test procedure, including the chamber calibration routine, is included in Appendix F.

Endurance times were measured on propylene-based and ethylene-based SAE Type I fluids mixed to a freeze point 10°C below ambient temperature. Tests were conducted on empty aluminum boxes.

Fluid dilution rates were measured during the fluid endurance tests. Surface temperatures were recorded with thermistor loggers installed on all empty aluminum boxes used for the tests.

Immediately following each endurance test, the surface temperature profiles were charted against fluid freeze point profiles. This information proved useful in understanding the observed endurance times and freezing patterns.

2.5.3 Results and Conclusions

2.5.3.1 Effect of droplet temperature on temperature of test surface

When the procedure for calibrating the chamber temperature was first used, it was quickly learned that the estimated guidelines for temperature differentials between the air and surface were too large. For example, for the condition *freezing drizzle at a rate of 13 g/dm²/h,* it had been estimated that an air temperature of -10°C would be necessary to achieve -3°C on the box surface. In fact, an air temperature of -3°C produced a stable box surface temperature of -3°C.

Appendix F presents plots of box surface temperature profiles experienced during the calibration process for some conditions. These profiles show the stabilized temperature before exposure to precipitation, the stabilized temperature when exposed to precipitation, and the temperature rise when freezing started.

The chamber ambient temperature differential needed to produce desired test temperatures on the test surface is shown in Table 2.1 for the various test conditions. The results showed that a combination of higher precipitation rates and colder temperatures were the only conditions for which a temperature differential was needed.

This exercise was aimed at ensuring that intended test temperatures existed on test surfaces when treated with Type I fluid. Because the fluid layer was very thin, it was assumed that the temperature of the top surface of the fluid layer was close to or the same as the test plate subsurface where the temperature was measured. It is not known whether this assumption would hold for a thicker layer of fluid, such as is produced by a Type IV fluid. With thicker fluid layers, a temperature gradient may exist where the fluid surface is warmer than the test plate underneath. The heat from the warmer fluid surface could flow from water droplets at temperatures above ambient and from the latent heat released as freezing initiates.

This test examined the influence of water droplets on the temperature of the test box surface. It was expected that water droplet temperature would affect the flat plate test surfaces to a lesser degree due to their faster rate of heat exchange via the exposed underside of the plate. This assumption should be investigated in future tests.

The temperature of the water in the lines just ahead of the spray nozzle was 2°C during these tests. It would be useful to examine the sensitivity of test surface temperature to the temperature of the source water. For example, does a source water temperature of 4°C affect test surface temperature and thus affect measured fluid endurance times?

From these tests, it was concluded that the source of heat causing the surface temperature to linger above ambient was only partly due to heat transfer from the warmer rain and drizzle drops. The other source was conjectured to be the latent heat of freezing, which was the heat released when the water started to freeze on the surface.

Table 2.1: Chamber Temperature Differential Needed for Production of Box Test Surface Temperature

Type of Precipitation	Rate (g/dm²/h)	Desired Test Surface Temperature (°C)	Temperature Differential Chamber vs. Surface (°C)
Freezing rain	25	-10	-2.5
Freezing rain	13	-10	-1.3
Freezing drizzle	13	-10	-0.5
Freezing drizzle	5	-10	-0.2
Freezing rain	25	-3	-0.7
Freezing rain	13	-3	0
Freezing drizzle	13	-3	0
Freezing drizzle	5	-3	0
Freezing fog	5	-25	0
Freezing fog	2	-25	0
Freezing fog	5	-10	0
Freezing fog	2	-10	0
Freezing fog	5	-3	0
Freezing fog	2	-3	0

2.5.3.2 Effect of latent heat of freezing

The following physical values related to the effect of the latent heat of freezing for water are noteworthy:

a) Latent heat of freezing for water is 80 calories/gram, and

b) One calorie of heat is required to raise the temperature of one gram of water by one degree Celsius.

If the OAT is -10°C, and the water droplet temperature is also -10°C, then upon freezing the following conditions apply:

a) For each gram of water that has frozen, 80 calories of heat is released;

b) The supercooling reserve is 10 calories (one calorie per degree Celsius, from 0°C to -10°C);

c) Consequently, at the instant of freezing, only 10 calories of heat can be absorbed by one gram of water before its temperature reaches 0°C, thus a surplus of 70 calories exists;

d) The portion of the gram of water that can be converted to ice is 10/80 or 1/8 of the gram;

e) The surplus of 70 calories of heat prevents 7/8 of the gram of water from freezing; and

f) The remaining 7/8 gram remains in a liquid state and only gradually converts to ice as the surplus 70 calories of heat is progressively dissipated into the underlying test surface and to the surrounding environment.

The mix of ice and water on the surface at this stage is, in effect, an ice-bath, and attempts to take on a temperature of 0°C. In the case of ambient temperature at -3°C, the test surface when freezing occurred did tend to stabilize at 0°C. The fluid had been completely diluted to water (fluid freeze point is 0°C) before start of freezing. In tests at colder ambient temperatures such as -10°C, some fluid still existed when freezing commenced and the intersection of the fluid freeze point and surface temperature profiles was below 0°C.

Tests were conducted only on the aluminum boxes, and the question arose whether the same result would be experienced with the standard flat plate on which previous fluid endurance tests had been conducted. It was believed that the construction of the empty aluminum box probably magnified the effect described above. The fact that the box cavity contained only air, and the bottom and sidewalls were insulated, limited heat transferred from the underside of the test surface. In the case of the flat test plate, the exposed underside allowed heat transfer to the ambient air and heat exchange with the cold chamber floor. This would cause the plate to cool at a rate greater than that of the box, which in turn would lead to a faster dissipation of the surplus latent heat of freezing.

The test conditions involved in the examination of the use of an empty aluminum box test surface for laboratory testing did not include snow. The development of the National Center for Atmospheric Research (NCAR) snowmaking machine is intended, at some point in the future, to move endurance testing for snow conditions indoors. Latent heat considerations may have a different influence for those tests. In the early part of the test, snowflakes melt into the fluid mix. At this stage, the latent heat of melting of the snowflakes will cause a drop in surface temperature, and will thereby shorten endurance times. A similar question applies for such tests: does the test surface temperature profile (indoors) represent the real wing temperature profile in field conditions following deicing for snow? The new outdoor test protocol for snow does not encounter this concern as the test surface is exposed to the same conditions (particularly wind) as the wing.

2.5.3.3 Endurance times

The endurance times generated at -3°C for all precipitation types were unexpectedly long, 20 to 25 minutes. A summary of endurance times at -3°C is included in Appendix F. Surface temperature and fluid freeze point profiles were plotted for each test condition, and the resulting charts are also included in the appendix.

2.5.4 Recommendation

This test protocol using the empty aluminum box proved unsatisfactory. It was decided to use the original laboratory procedure for determining HOT times, based on the standard aluminum plate. This decision conformed to recommendations from the study that examined a test protocol for Type I fluid endurance tests in an outdoor environment, which is reported in TC report TP 13827E, *SAE Type I Fluid Endurance Time Test Protocol* (1). In that study, it was recommended that indoor laboratory tests continue to be used for the existing SAE Type I fluid endurance test procedure. This recommendation was based on findings that showed that the resulting cooling profile for the standard test plate was a good representation of the generic cooling profile for wing leading edges. This is the same criterion that was used to select a surface for outdoor tests.

Figure 2.2 illustrates the cooling profiles for the generic wing leading edge and the surface selected for outdoor tests, both in a natural outdoor environment subjected to various winds, and the standard test plate in a laboratory environment in calm conditions. The profile for the standard test plate lies just below the generic cooling profile for wing leading edges, and as a result, would generate endurance times that are slightly conservative.

It was recommended that the next set of fluid endurance tests conducted in the laboratory include logging of plate temperatures and measurement of fluid dilution rates to examine whether the latent heat effect is present in the standard HOT tests using flat plates. The data from the subsequent laboratory fluid endurance tests is reported in TC report TP 13991E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter* (3).

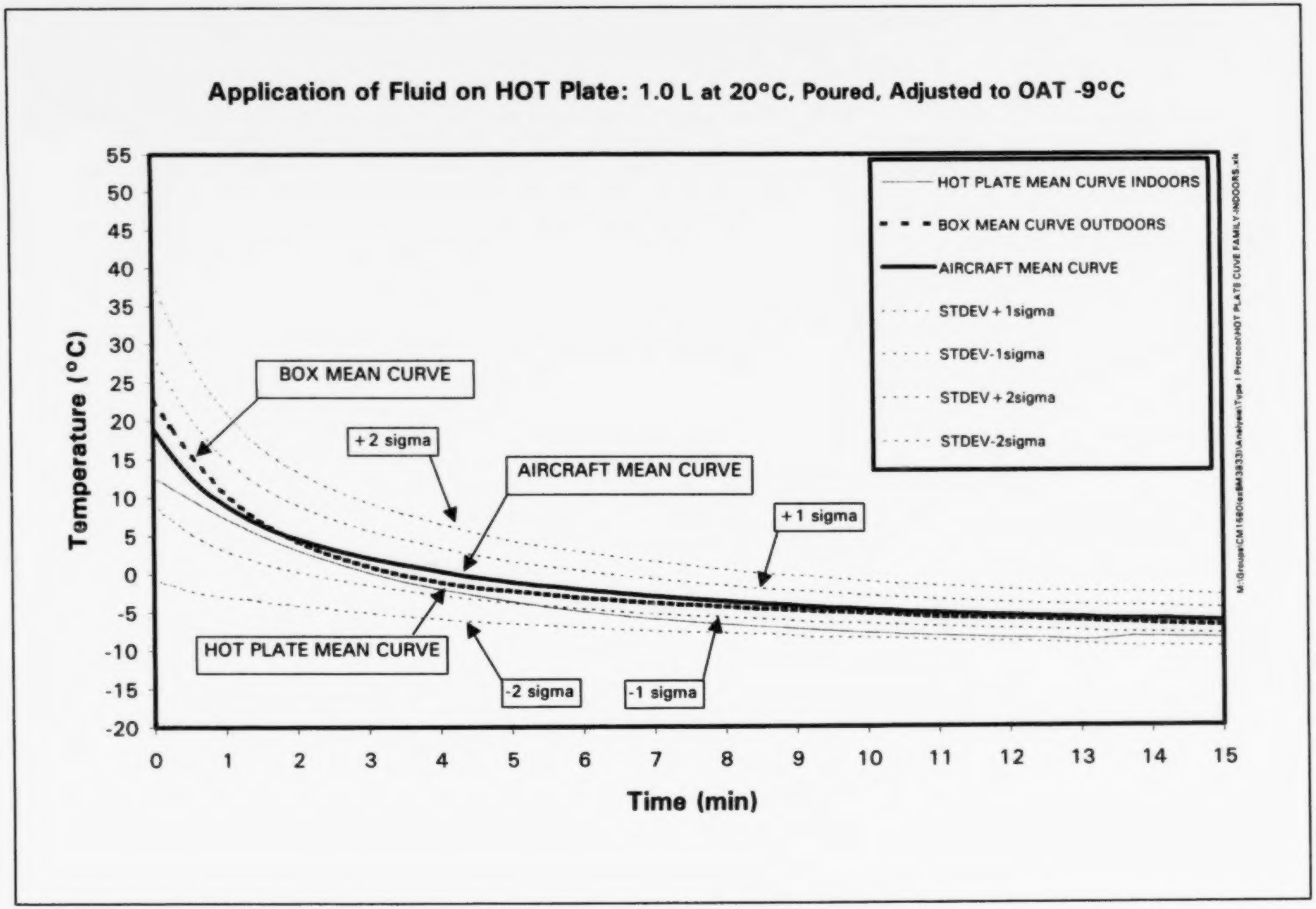

Figure 2.2: HOT Plate Temperature Profiles (Indoors) – Comparison to Average Wing and Box

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3

3. FORMULATION OF TEST PROTOCOL FOR SAE TYPE I FLUID ENDURANCE TIMES IN NATURAL SNOW

3.1 Background

The 1999-2000 winter series of endurance time tests on SAE Type I fluids on flat plates resulted in recommended holdover times for snow that were significantly shorter than those previously published. Nevertheless, the older holdover times of 6 to 15 minutes had been used without incident since their implementation.

The reduction in fluid endurance times led to discussion at industry meetings and to the general realization that the test protocol was suspect. It was generally believed that the reduction in endurance times was the result of a test method that did not consider the contribution of the transfer of heat from the heated fluid to the wing surface.

As a result of this concern, APS was directed to develop a test protocol for measuring endurance times for SAE Type I fluids that would reflect real field operations. The ideal protocol would simulate the full nature of actual de/anti-icing operations on real wings in the natural environment.

3.2 Development of Test Protocol

To achieve this objective, a series of activities was conducted during the winter 2000-01. These activities were reported in TC report TP 13827E, *SAE Type I Fluid Endurance Time Test Protocol* (1). These activities progressively provided information to support development of a new test protocol. In overview, these activities were:

a) Reviewing pertinent data from various test reports;

b) Collecting data on wing temperature decay rate to serve as a benchmark for comparison;

c) Selecting a suitable test surface;

d) Examining prospective test surfaces in laboratory and field tests;

e) Comparing test results from prospective test surfaces with data from tests on wings;

f) Conducting fluid endurance time tests on prospective test surfaces;

g) Conducting tests with a JetStar test wing in laboratory conditions and with operational aircraft in natural conditions to examine how prospective test surfaces correspond to aircraft wings; and

h) Defining and documenting test procedures, using the selected test surface.

3.3 Description of a New Test Protocol for Snow in Natural Conditions

The recommended procedure resulting from the foregoing research activities for Type I fluid endurance tests in outdoor natural snow conditions involved the following:

a) Use an empty aluminum box. The recommended surface to satisfy this requirement was an empty 7.5 cm aluminum box, treated according to the procedure outlined below;

b) Clean all contamination from the test surface and wet the surface with a small amount of test fluid at ambient temperature prior to applying test fluid;

c) Apply 0.5 L of test fluid heated to 60°C (with an acceptance range of +2°C and 0°C) using a fluid spreader positioned along the top edge of the test surface; and

d) Position a spreader horizontally at the top end of the test plate, supported at a fixed distance above the plate surface by wood forms at each end. The spreader is constructed from a length of PVC pipe, 30 cm long and with a 15 cm diameter. The upper side of the pipe has a large opening, which allows fluid to be poured quickly into the pipe. The underside of the pipe has 12 drain holes, 4.8 mm (3/16 in.) diameter, at equal intervals along the length.

3.3.1 Tests on Operational Aircraft in Natural Conditions

One of the activities leading to final acceptance was a test in natural snow conditions to compare fluid endurance times from the proposed test procedure to endurance times experienced on operational aircraft wings.

Because these tests could not be conducted during winter 2000-01, they were planned for winter 2001-02. The test procedure is given in Appendix G. Although the test planning was completed early in the season, there was only one occasion when a potentially suitable overnight snowstorm occurred (night of Jan. 31/Feb. 1, 2002).

In the late day, the forecasted snow system moved to the south, putting Montreal on its northern edge. Winds of 35 to 50 km/h were forecast. Although marginal, the forecast was considered adequate to support testing.

An American Eagle Saab 340 was intended for use during its overnight stay at Dorval Airport. It was scheduled to arrive at 00:05, Feb. 1 2002. Just prior to midnight, the ground handler requested the cancellation of the test due to the high winds and problems with the crew.

The test plan had included simultaneous tests on the JetStar test wing and these continued despite the Saab 340 cancellation.

During the test session, it did not actually snow and the only valid data gathered was for surface temperature cooling rates. Surface temperatures were logged for the test surfaces and the wing, and resulting temperature profiles are given in Appendix G.

Three tests were conducted on the JetStar test wing. The first two were conducted during light freezing drizzle, with some ice on the wing. Simultaneous tests were conducted using the new outdoor Type I test protocol (on the empty aluminum box) and with the standard HOT test protocol (on the standard aluminum test plate). The quantity of deicing fluid applied to the wing was relatively light during these two tests; this was believed to be because the thin layer of ice was difficult for the deicing operator to see.

For the third test, a thick layer of snow was built up on the wing using snow taken from the ramp. The deicing operator then cleaned the wing. Considerably more fluid was used in this test. Simultaneous tests using the new outdoor Type I test protocol (on the empty aluminum box) and the standard HOT test protocol were not conducted during this test.

Table 3.1 shows the amount of fluid applied in each of the three tests. The fluid amount per square metre is calculated based on the wing area (25 m^2).

Table 3.1: Fluid Amounts for JetStar Test Wing Deicing

Run	Fluid Amount (L)	L/m^2
1	85	3.4
2	59	2.4
3	176	7.0

The amount of fluid applied in the third test was typical of amounts applied during medium snowfalls in actual operations, reported in TC report TP 13478E, *Aircraft Deicing Fluid Freeze Point Buffer Requirements for Deicing Only Conditions* (4).

In Figure 3.1, the wing surface temperature profiles resulting from this test are compared to plate and box surface temperature profiles. For this comparison, the plate and box surface temperature profiles from Run 2 are used because simultaneous tests on these surfaces were not conducted during test 3. The temperature profile for the box lies along the bottom of the family of wing curves, near that of the leading edge. This provided further evidence that the new test protocol is a good representation of the wing deicing operation in natural conditions. The standard HOT test produced a temperature profile well below those generated from the wing.

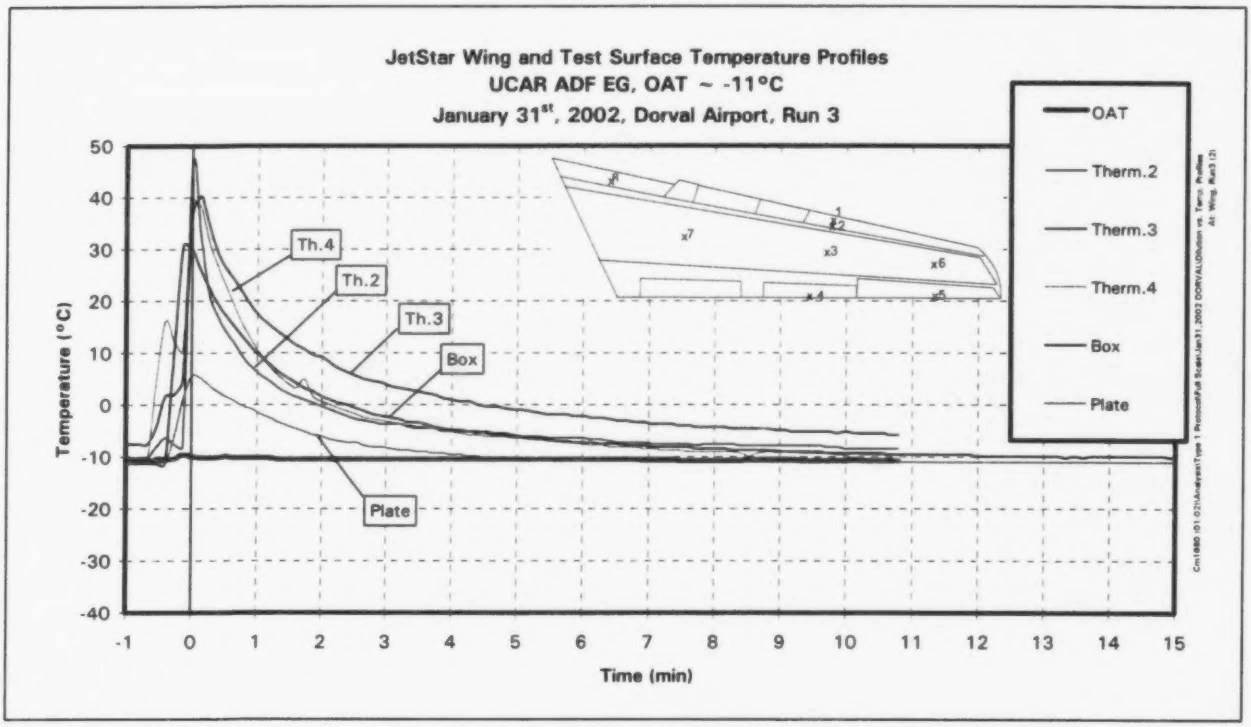

Figure 3.1: JetStar Wing and Test Surface Temperature Profiles

4

4. OUTDOOR SNOW TESTS USING THE NEW TYPE I PROTOCOL

This section describes the natural snow test data collected during the winter of 2001-02 using the newly developed Type I Protocol (see TC report TP 13827E *SAE Type I Fluid Endurance Time Test Protocol* (1)). The tests examined in this study were done by APS and AMIL, generally using the same procedure.

4.1 Background

For several years, the historical HOT guidelines for SAE Type I fluids established a 6 to 15-minute HOT for snow precipitation, irrespective of temperature (Table 4.1).

Table 4.1: Historical SAE Type I Fluid HOT Guidelines Prior to 2000

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F	FROST	FREEZING FOG	**SNOW**	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
above 0°	**above 32°**	0:45	0:12-0:30	**0:06-0:15**	0:05-0:08	0:02-0:05	0:02-0:05	**CAUTION No holdover time guidelines exist**
0 to -10	**32 to 14**	0:45	0:06-0:15	**0:06-0:15**	0:05-0:08	0:02-0:05		
below -10	**below 14**	0:45	0:06-0:15	**0:06-0:15**				

In the winter of 1999-2000, a series of endurance time tests was conducted with SAE Type I fluids, using test parameters developed to test Type II and IV fluids. These tests resulted in a recommendation at the 2000 annual meeting of the SAE G-12 HOT Subcommittee held in Toulouse, France, that holdover times for snow be reduced to values significantly shorter than those previously published.

The mechanism of Type I fluid failure has become better understood through investigations on the contribution of surface heat to endurance times. The time of freezing can be graphically illustrated by examining the intersection of the fluid dilution curve with the surface temperature decay curve. Altering the factors controlling either of the two curves will change the time to freeze as follows:

a) A slower dilution rate, as in the case for full-strength fluid at low precipitation rates, will delay the onset of freezing (the fluid dilution curve and surface temperature curve will intersect at a later time); and

b) A faster surface temperature decay rate, as in the case of application of a cooler fluid, will result in earlier freezing (the curves will intersect earlier).

4.2 Changes to the Format of the HOT Table

In 2001-02, the Type I fluid HOT table format underwent a thorough examination. Research in previous years had indicated a need to make changes to the format. Some of the changes have been presented and accepted by the community, others have yet to be formally accepted. Two major changes have now been implemented to the format of the Type I fluid holdover time table:

a) The current temperature ranges of *above 0°C* and *from 0°C to -10°C* have been modified to *above -3°C* and *from -3°C to -10°C;* and

b) A column for *light snow* was added (3 g/dm^2/h or 5 g/dm^2/h to 10 g/dm^2/h).

The generic Type I guidelines produced by the FAA for use in 2002-03 winter operations contain *light snow* and *moderate snow* columns, as well as *-3°C and Above*, *-3°C to -6°C*, and *-6°C to -10°C* temperature breakdowns.

TC selected a lower limit of 3 g/dm^2/h to be used for the *light snow* column; however, the FAA selected a lower limit of 5 g/dm^2/h. The TC position has taken into consideration the very low rates that are experienced in Northern Canada at low temperatures. The FAA position, which results in shorter endurance times at the lower limit, is balanced by the FAA rule that adds 5 minutes to a pre-take off contamination check.

A detailed account of the changes to the HOT table format is documented in TC report TP 13993E, *Impact of Winter Weather on Holdover Time Table Format* (5).

As a result of the -3°C row, endurance time tests have been conducted under precipitation conditions of freezing fog, freezing drizzle, and light freezing rain at a temperature of -3°C. The procedure and results of these tests are presented in TC report TP 13991E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter* (3).

4.3 Methodology

4.3.1 Test Sites

Natural snow tests were conducted by APS at a test site located at Dorval Airport. The location of the site is shown on the plan view of the airport in Figure 4.1. Photos 4.1 and 4.2 were taken at the test site and show the trailer and the associated equipment. This same trailer was also used in past winters. The APS test site is located near Environment Canada's Atmospheric Environment Services automated weather observation station (Photo 4.3).

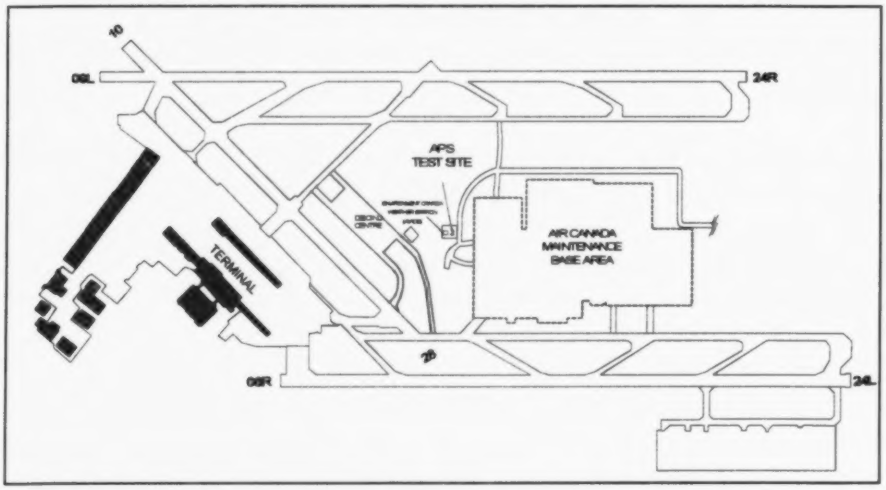

Figure 4.1: Location of APS Test Site at Dorval Airport

AMIL performed natural snow tests using a similar protocol at its facility located in Chicoutimi, Quebec.

4.3.2 Description of Test Procedures

Historically, Type I fluid endurance time testing had been done according to a procedure developed by the SAE G-12 Holdover Time Subcommittee on aircraft de/anti-icing over the past decade. Each year this procedure had been subject to minor modifications to address the wishes and concerns within the subcommittee. In essence, the core of the procedure remained unmodified and it had been used since its inception. The procedure can be found in Appendix B of TC report TP 13991E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter* (3). According to this procedure, tests are conducted on standard aluminum flat plates, using fluid at

20°C. The fluid is poured onto the plates straight from a manageable container, until a uniform fluid thickness is obtained on the entire test surface.

In an attempt to develop a protocol for measuring endurance times for SAE Type I fluids that would better reflect the full nature of actual de/anti-icing operations on aircraft wings in a natural environment, a series of activities was conducted in the winter of 2000-01. These progressively provided information to support development of a new test protocol.

The new protocol consisted of using a new test surface that provided a thermal equivalent to the wing leading edge. The new surface was determined to be an empty aluminum box insulated on all sides except the top. The recommended test temperature for the Type I fluid was 60°C and the recommended quantity was 0.5 L. The fluid was applied along the top edge of the test surface using a fluid spreader. The APS procedure for the test is included in Appendix H.

Fluid endurance tests on standard plates using the conventional HOT procedure were also conducted to provide a baseline for comparison.

Type I endurance time tests on empty aluminum boxes at Quebec City Airport were also considered. These tests were not carried out as FAA/TC did not want to proceed, primarily due to the difficulty experienced by personnel to determine the failure calls and to properly follow procedures. This procedure for conducting tests at Quebec City was developed but not used and is included in Appendix I.

The surfaces on the typical test stand for testing with the new protocol were positioned as described in Figure 4.2 and Table 4.2.

Pos. 6	**Pos. 5**	**Pos. 4**	**Pos. 3**	**Pos. 2**	**Pos. 1**
BOX	***BOX***	***BOX***	***PLATE***	***PLATE***	
Ethylene or Propylene Std. Mix	**Propylene 10° Buffer**	**Ethylene 10° Buffer**	**Propylene 10° Buffer**	**Ethylene 10° Buffer**	**RATE PAN**

Figure 4.2: APS Test Stand Positions

In addition to the original procedure, APS measured surface temperatures and fluid dilutions as the test progressed to gain a better understanding of the phenomena that take place as the fluid becomes diluted.

Table 4.2: APS Test Stand Positions

Stand Pos.	Surface Type	Fluid		Fluid Conc.	Fluid Type*
		Amount (L)	Temp (°C)		
1	Rate Pan	DNA	DNA	DNA	DNA
2	Standard plate for ET test	1	20	10° Buffer	E
3	Standard plate for ET test	1	20	10° Buffer	P
4	7.5 cm box (empty)	0.5	60	10° Buffer	E
5	7.5 cm box (empty)	0.5	60	10° Buffer	P
6	7.5 cm box (empty)	0.5	60	Std. mix	E or P

* E – Ethylene (Dow/UCAR EG ADF)
P – Propylene (Dow/UCAR PG ADF)

Starting on January 31, 2002, surface temperature logging was implemented. Using aluminum tape, one thermistor probe was mounted on each of the three boxes and two plates at the 15 cm line. The connection was designed to permit fluid flow and to last for the rest of the test season. A SmartReader Eight-Channel temperature logger was used to measure and record temperature. This temperature logger ran continuously and independently of any external power supply or computer; the logger constantly measured and recorded readings from any enabled channels. The sampling rate (how often the logger takes readings) was set to eight seconds, the smallest possible increment. One reading was taken every eight seconds and saved to memory.

Fluid dilution rates were measured at the 15 cm line, using a Misco 10431VP refractometer. These measurements were obtained to determine the concentration of the fluid on the test surface until the fluid failed. The Brix value was originally measured in the container before pouring. The second measurement was obtained right after pouring on the test surface, and typically a few more times until the fluid failed. The last Brix value was recorded at standard plate failure.

Photo 4.2 was taken at the test site on March 18, 2002, and shows the stand used for Type I testing.

AMIL conducted tests at Chicoutimi using a similar protocol. The procedure used by AMIL differed in at least two ways from the one used by APS. Part of the testing done by AMIL was performed without the use of thermos bottles to maintain the fluid temperature, and AMIL was unable to position its stands to face into the wind. The procedure used by AMIL for the tests is included in Appendix J.

4.3.3 Equipment

The equipment used was, in general, the same as that for the fluid holdover time tests. A comprehensive description of the equipment can be found in TC report TP 13991E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter* (3). The candidate test surfaces used for these tests were:

a) Two standard test plates; and

b) Three 7.5 cm empty aluminum boxes.

In addition to the test surface, several other pieces of equipment were required. A windshield and fluid spreader device, with 12 holes, were used for applying fluids. A handheld anemometer was used to measure wind speed near the test stand. A SmartReader Eight-Channel temperature logger and thermistor probes were used for logging test surface temperatures. A Misco 10431VP refractometer was used for fluid dilution rate measurements.

For this project, the measuring instruments used to record various data were provided by APS and Environment Canada, and these instruments were calibrated according to their standards.

4.3.4 Fluids

Tests were conducted with ethylene-based and propylene-based Type I fluids. Fluids applied to the cold-soak box test surfaces were heated to 60°C. Fluids for standard ET tests were heated to 20°C.

The fluids tested by APS and AMIL are presented in Table 4.3.

Table 4.3: Fluids Tested by APS and AMIL

Fluid Manufacturer	Fluid Trade Name	Tested by
DOW	UCAR EG ADF	APS and AMIL
DOW	UCAR PG ADF	APS and AMIL
DOW	UCAR ADF XL54	APS and AMIL
DOW	UCAR PG ADF (FFP -34°C)	APS
Octagon	Octaflo EF	AMIL
Octagon	Octaflo EF Premix	AMIL

Type I fluids are usually obtained from manufacturers in concentrated form. Each manufacturer sets its own concentration based on performance requirements and cost. For example, by weight UCAR ADF XL54 nominally contains 54 percent ethylene glycol as a freezing point depressant.

Standard mix solutions (that is, UCAR ADF XL54) and 10°C buffer solutions were used for the holdover time testing conducted during the winter of 2001-02. "10°C buffer" signifies that for any test, the test solution must possess a freeze point 10°C below that of the ambient test temperature.

Whenever fluid dilution was required, the concentrations were adjusted by mixing with hard water and verified by measuring the refractive index of the resulting solution. The hard water was produced according to Aerospace Material Specifications AMS 1424. To produce 18 L of hard water, 6.54 g of calcium acetate monohydrate and 5.04 g of magnesium sulfate heptahydrate were weighed and added to 18 L of distilled water.

Table 4.4 illustrates the fluid refraction (dilution) for the corresponding outside air temperature and fluid freeze point for the fluids tested by APS. The Misco 10431VP refractometer is calibrated to read the fluid refraction in degrees Brix.

The Brix-to-refraction index conversion was provided by MISCO Products Division, and is presented in Table 4.5.

4.3.5 Personnel

The test personnel at the Dorval test site were mainly technicians and university students supervised by APS project staff.

The supplementary objectives requested of APS were to measure test surface temperatures and fluid dilution progressively towards failure, and these required more personnel. Due to the complexity of testing, four testers were needed to successfully complete all tasks required by the procedure.

One technician was required for each of the following tasks:

a) Call failures and assist in preparing fluid samples;
b) Prepare and help pour fluids;
c) Measure rates and wind velocity; and
d) Measure Brix values.

Table 4.4: Fluid Dilutions

OAT (°C)	FFP (°C)	UCAR PG ADF				UCAR EG ADF			
		Glycol %	Brix	Glycol for 8 L	Water for 8 L	Glycol %	Brix	Glycol for 8 L	Water for 8 L
10	0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	8.0
9	-1	2.7	1.5	0.2	7.8	3.0	1.5	0.2	7.8
8	-2	5.0	3.5	0.4	7.6	4.5	3.0	0.4	7.6
7	-3	10.0	6.0	0.8	7.2	7.5	4.8	0.6	7.4
6	-4	11.5	7.5	0.9	7.1	10.0	6.5	0.8	7.2
5	-5	15.0	10.0	1.2	6.8	12.0	8.0	1.0	7.0
4	-6	20.0	13.3	1.6	6.4	14.5	9.5	1.2	6.8
3	-7	22.0	14.0	1.8	6.2	16.0	10.5	1.3	6.7
2	-8	24.5	16.0	2.0	6.0	18.5	12.0	1.5	6.5
1	-9	26.0	17.3	2.1	5.9	21.5	13.5	1.7	6.3
0	-10	27.7	18.4	2.2	5.8	22	14	1.8	6.2
-1	-11	30.0	19.8	2.4	5.6	23	15	1.8	6.2
-2	-12	30.9	20.5	2.5	5.5	24.5	16	2.0	6.0
-3	-13	32.4	21.5	2.6	5.4	26	17	2.1	5.9
-4	-14	33.9	22.3	2.7	5.3	28	18	2.2	5.8
-5	-15	35.0	22.8	2.8	5.2	30	19	2.4	5.6
-6	-16	36.7	24.2	2.9	5.1	31	19.75	2.5	5.5
-7	-17	38.1	25.0	3.0	5.0	32	20.5	2.6	5.4
-8	-18	39.4	25.8	3.1	4.9	33.5	21.25	2.7	5.3
-9	-19	40.0	27.2	3.2	4.8	34.5	21.75	2.8	5.2
-10	-20	41.9	27.5	3.4	4.6	36	22.5	2.9	5.1
-11	-21	43.1	27.8	3.4	4.6	37	23	3.0	5.0
-12	-22	45.0	28.6	3.6	4.4	38	23.75	3.0	5.0
-13	-23	45.4	29.0	3.6	4.4	39	24.5	3.1	4.9
-14	-24	46.4	29.5	3.7	4.3	40	25	3.2	4.8
-15	-25	47.5	30.0	3.8	4.2	41	25.5	3.3	4.7
-16	-26	48.5	30.5	3.9	4.1	42	26	3.4	4.6
-17	-27	49.5	31.0	4.0	4.0	43	26.5	3.4	4.6
-18	-28	50.0	31.4	4.0	4.0	44	27	3.5	4.5
-19	-29	51.3	31.8	4.1	3.9	45	27.5	3.6	4.4
-20	-30	52.2	32.1	4.2	3.8	45.75	28	3.7	4.3
-22	-32	53.9	32.8	4.3	3.7	47	28.75	3.8	4.2
-25	-35	56.1	34.0	4.5	3.5	49	30	3.9	4.1
-30	-40	60.0	36.3	4.8	3.2	53	32	4.2	3.8
Standard Mix		55.0	33.8	4.4	3.6	57	33.5	4.6	3.4

Table 4.5: Conversion of Brix to Refraction Index at 20°C

BRIX	0.0	0.25	0.50	0.75	BRIX	0.00	0.25	0.50	0.75
0	1.3330	1.3334	1.3337	1.3341	26	1.3741	1.3745	1.3749	1.3754
1	1.3344	1.3348	1.3351	1.3355	27	1.3758	1.3763	1.3767	1.3772
2	1.3359	1.3363	1.3366	1.3370	28	1.3776	1.3780	1.3785	1.3789
3	1.3373	1.3377	1.3381	1.3384	29	1.3794	1.3798	1.3803	1.3807
4	1.3388	1.3392	1.3395	1.3399	30	1.3812	1.3816	1.3821	1.3825
5	1.3403	1.3407	1.3410	1.3414	31	1.3830	1.3834	1.3839	1.3843
6	1.3418	1.3421	1.3425	1.3429	32	1.3848	1.3852	1.3857	1.3862
7	1.3433	1.3437	1.3440	1.3444	33	1.3866	1.3871	1.3875	1.3880
8	1.3448	1.3452	1.3455	1.3459	34	1.3885	1.3889	1.3894	1.3899
9	1.3463	1.3467	1.3471	1.3475	35	1.3903	1.3908	1.3913	1.3917
10	1.3478	1.3482	1.3486	1.3490	36	1.3922	1.3927	1.3931	1.3936
11	1.3494	1.3498	1.3502	1.3506	37	1.3941	1.3946	1.3950	1.3955
12	1.3509	1.3513	1.3517	1.3521	38	1.3960	1.3965	1.3970	1.3974
13	1.3525	1.3529	1.3533	1.3537	39	1.3979	1.3984	1.3989	1.3994
14	1.3541	1.3545	1.3549	1.3553	40	1.3999	1.4004	1.4008	1.4013
15	1.3557	1.3561	1.3565	1.3569	41	1.4018	1.4023	1.4028	1.4033
16	1.3573	1.3577	1.3581	1.3585	42	1.4038	1.4043	1.4048	1.4053
17	1.3589	1.3593	1.3597	1.3602	43	1.4058	1.4063	1.4068	1.4073
18	1.3605	1.3610	1.3614	1.3618	44	1.4078	1.4083	1.4088	1.4093
19	1.3622	1.3626	1.3630	1.3634	45	1.4098	1.4103	1.4108	1.4113
20	1.3638	1.3643	1.3647	1.3651	46	1.4118	1.4123	1.4128	1.4133
21	1.3655	1.3660	1.3664	1.3668	47	1.4139	1.4144	1.4149	1.4154
22	1.3672	1.3676	1.3680	1.3685	48	1.4159	1.4164	1.4170	1.4175
23	1.3689	1.3693	1.3698	1.3702	49	1.4180	1.4185	1.4190	1.4196
24	1.3706	1.3711	1.3715	1.3719	50	1.4201			
25	1.3723	1.3728	1.3732	1.3736					

4.3.6 Test Plan and Sequence

The objective was to conduct at least 20 tests for each surface and fluid type. In actual practice, almost twice the number of tests originally required by the procedure were run. The number of tests conducted, for each surface and fluid type, are presented in the discussion of results in Subsection 4.4.

Two standard test plates and three 7.5 cm empty aluminum boxes were simultaneously placed on the test stand for each test. In an attempt to maintain the precipitation rate as constant as possible, all five tests were run at the same time and always following the same sequence. First, the fluid was applied on the boxes with the use of a spreader (one spreader for each box). Subsequently, the fluid was poured on the plates. Since the endurance times of the fluids poured onto the boxes were expected to be longer than those poured on standard test plates, the fluid was first applied to the boxes.

4.3.7 Data Forms

The data forms used for testing are included in the procedure and are given in Appendix H. In addition to the original procedure, APS conducted fluid dilution measurements during testing. The information collected was recorded on the form presented in Figure 4.3.

4.4 Description and Processing of Data

This section provides a description of Type I ET tests conducted in natural snow by APS and AMIL. Natural snow tests were conducted at the APS test site located at Dorval Airport and in Chicoutimi, Quebec.

4.4.1 Log of Tests – APS

During the winter of 2001-02, APS conducted a series of endurance time tests using the newly developed Type I protocol. Two fluids provided by the same manufacturer, Dow Chemical, were tested. These tests included different concentrations and test surfaces. Table 4.6 shows a summary of the number of tests performed by APS.

A summary of the conditions for tests conducted by APS during the winter of 2001-02 is presented below:

a) 11 snow events;
b) 210 tests;
c) Snowfall rate between 0.9 and 60.5 $g/dm^2/h$;
d) Outside air temperature between 1.0 and -13.9°C; and
e) Wind speed between 4.9 and 47.5 km/h.

DATE: ______________ PERFORMED BY: ______________

RUN #: ______________ WRITTEN BY: ______________

STAND: ______________ LOCATION: ______________

BRIX					
Plate: Fluid:		Plate: Fluid:		Plate: Fluid:	
TIME	15 cm LINE	TIME	15 cm LINE	TIME	15 cm LINE

Figure 4.3: Fluid Brix Data Form

Table 4.6: Summary of APS Endurance Time Tests Using the New Type I Protocol

Fluid Name	Fluid Freezing Point (°C)	Number of Tests on Boxes	Number of Tests on Plates
UCAR EG ADF	10°C below OAT	42	43
UCAR PG ADF	10°C below OAT	38	41
UCAR ADF XL54	-43	35	–
UCAR PG ADF (FFP -34°C)	-34	11	–

The complete log of tests is presented in Table 4.7. The log gives all the pertinent information needed to understand the tests run by APS. Following is a brief explanation of the column headings in Table 4.7:

Test no.:	Exclusive number identifying each test;
Date:	The date on which each test was run;
Fluid Name:	The fluid trade name, given by the manufacturer;
Surface:	The surface on which the test was run (box or plate);
Start Brix/End Brix:	Brix (dilution) values measured from the fluid of each test just before pouring (Start Brix) and at standard failure (End Brix) at the 15 cm line;
Fluid Temperature:	The temperature of the fluid poured onto the test surface, measured in °C;
Fail Time:	The endurance time of the fluid (in minutes), as determined by the time difference between the moment at which the pouring of the fluid started and at standard failure;
Average Rate:	Average precipitation rate for the duration of each test, measured in $g/dm^2/h$;
Outside Air Temperature:	The average outside ambient temperature for the duration of each test, measured in °C;
Wind Speed:	Average wind speed for the duration of each test, measured at a height of 10 m in kilometres per hour;
Wind Direction:	The average direction in which the wind was blowing for the test duration, measured in degrees. Zero degrees represents Magnetic North; and
Visibility:	The average visibility for the duration of each test, measured in kilometres. Visibility represents the greatest distance toward the horizon that prominent objects can be identified visually with the naked eye.

APS conducted fluid Brix measurements at the 15 cm line as the fluid gradually approached failure. The test surface temperatures were measured using thermistors (one for each test surface) and a data logger. Using this information, a graphic representation of the two parameters (plate temperature and fluid dilution) was created for almost all the tests conducted by APS. The icing intensity, measured in g/dm²/h, was also plotted on the charts to give a complete depiction of the phenomena that took place during testing. The entire set of charts for the winter of 2001-02 is provided in Appendix K.

Table 4.7: Log of Type I Protocol Tests (APS)

Test no.	Date	Fluid Name	Surf.	Start Brix (degrees)	End Brix (degrees)	Fluid Temp (°C)	Fail Time (min)	AVG RATE (g/dm²/h)	Environment Canada Data			
									OAT (°C)	Wind Speed (km/h)	Wind Dir (degrees)	Visibility (km)
1	Jan-9-02	UCAR EG ADF	Plate	14.5	N/A	20	5.4	16.7	-0.6	20.4	156	0.8
2	Jan-9-02	UCAR EG ADF	Plate	14.5	N/A	20	4.4	16.7	-0.6	20.4	156	0.8
3	Jan-9-02	UCAR EG ADF	Box	14.0	N/A	62	8.3	17.9	-0.6	21.4	156	0.8
4	Jan-9-02	UCAR EG ADF	Box	14.0	N/A	62	8.5	18.0	-0.6	21.4	156	0.8
5	Jan-9-02	UCAR ADF XL54	Box	34.5	N/A	63	9.8	17.7	-0.6	21.2	156	0.8
6	Jan-13-02	UCAR EG ADF	Plate	14.8	2.0	20	33.9	2.3	1.0	11.5	199	5.0
7	Jan-13-02	UCAR PG ADF	Plate	20.0	1.0	20	33.4	2.3	1.0	11.5	199	4.7
8	Jan-13-02	UCAR EG ADF	Box	14.8	0.5	60	37.9	3.0	1.0	11.5	199	4.3
9	Jan-13-02	UCAR PG ADF	Box	20.0	0.5	60	38.6	3.2	1.0	11.4	199	4.3
10	Jan-15-02	UCAR EG ADF	Plate	21.3	10.0	20	8.6	8.5	-7.9	26.3	42	1.5
11	Jan-15-02	UCAR PG ADF	Plate	24.0	11.5	20	9.7	7.8	-7.8	26.4	42	1.6
12	Jan-15-02	UCAR EG ADF	Box	21.3	8.0	60	16.2	8.2	-7.8	26.5	41	1.7
13	Jan-15-02	UCAR PG ADF	Box	29.0	11.0	60	17.2	7.8	-7.8	26.6	40	1.8
14	Jan-15-02	UCAR ADF XL54	Box	34.0	9.0	60	19.5	7.1	-7.8	27.1	40	1.8
15	Jan-15-02	UCAR EG ADF	Plate	21.3	11.5	20	54.2	0.9	-7.5	25.2	37	7.6
16	Jan-15-02	UCAR PG ADF	Plate	24.0	14.0	20	30.5	0.9	-7.7	27.1	39	7.0
17	Jan-15-02	UCAR EG ADF	Box	21.3	12.0	60	74.5	0.9	-7.6	25.3	34	8.8
18	Jan-15-02	UCAR PG ADF	Box	24.0	15.0	60	71.9	0.9	-7.6	25.2	34	8.9
19	Jan-15-02	UCAR ADF XL54	Box	34.0	12.0	60	79.3	0.9	-7.6	25.2	34	9.0
20	Jan-15-02	UCAR EG ADF	Plate	21.3	10.0	20	43.3	1.3	-7.1	23.9	31	5.0
21	Jan-15-02	UCAR PG ADF	Plate	24.0	12.0	20	41.1	1.1	-7.1	23.8	31	5.1
22	Jan-15-02	UCAR EG ADF	Box	21.3	9.0	60	50.2	2.0	-7.1	24.0	31	4.9
23	Jan-15-02	UCAR PG ADF	Box	24.0	12.0	60	50.3	2.1	-7.1	24.0	31	4.9
24	Jan-15-02	UCAR PG ADF (FFP -34°C)	Box	33.0	13.0	60	50.0	2.1	-7.1	24.0	31	4.9
25	Jan-15-02	UCAR EG ADF	Plate	21.2	9.0	20	32.4	1.3	-6.6	25.3	30	3.2
26	Jan-15-02	UCAR PG ADF	Plate	24.0	13.0	20	28.3	1.3	-6.6	25.9	31	3.2
27	Jan-15-02	UCAR EG ADF	Box	21.3	8.0	60	65.7	1.3	-6.4	23.4	31	4.0
28	Jan-15-02	UCAR PG ADF	Box	24.0	11.0	60	65.2	1.3	-6.4	23.4	31	4.0
29	Jan-15-02	UCAR ADF XL54	Box	33.8	9.0	60	64.5	1.3	-6.4	23.4	31	4.0
30	Jan-15-02	UCAR EG ADF	Plate	19.8	6.0	20	9.6	6.2	-5.2	18.9	29	3.0
31	Jan-15-02	UCAR PG ADF	Plate	21.0	8.0	20	8.3	6.2	-5.2	18.5	28	3.0
32	Jan-15-02	UCAR EG ADF	Box	19.8	5.0	60	13.5	6.2	-5.2	19.2	29	3.0
33	Jan-15-02	UCAR PG ADF	Box	21.0	8.5	60	13.5	6.4	-5.2	19.2	29	3.0
34	Jan-15-02	UCAR PG ADF (FFP -34°C)	Box	33.8	7.0	60	12.8	6.4	-5.2	19.1	29	2.9
35	Jan-15-02	UCAR EG ADF	Plate	19.8	8.0	20	10.7	5.0	-5.1	22.2	32	1.8
36	Jan-15-02	UCAR PG ADF	Plate	21.0	10.0	20	9.7	4.9	-5.1	22.2	31	1.8
37	Jan-15-02	UCAR EG ADF	Box	19.8	6.0	60	14.4	5.1	-5.1	21.7	31	1.9
38	Jan-15-02	UCAR PG ADF	Box	21.0	8.0	60	14.5	5.6	-5.1	21.5	31	1.9
39	Jan-15-02	UCAR ADF XL54	Box	33.8	7.0	60	15.0	6.2	-5.1	21.3	31	2.0
40	Jan-15-02	UCAR EG ADF	Plate	19.8	5.0	20	7.8	7.9	-5.0	17.1	23	1.1
41	Jan-15-02	UCAR PG ADF	Plate	21.0	7.0	20	7.0	7.9	-5.0	17.1	23	1.1
42	Jan-15-02	UCAR EG ADF	Box	19.8	3.5	60	11.9	8.2	-5.0	17.0	23	1.1
43	Jan-15-02	UCAR PG ADF	Box	21.0	4.0	60	11.0	8.3	-5.0	17.0	23	1.1
44	Jan-15-02	UCAR PG ADF (FFP -34°C)	Box	33.8	5.0	60	11.1	8.7	-5.0	17.3	23	1.1
45	Jan-17-02	UCAR ADF XL54	Box	33.0	7.0	60	18.7	3.3	-4.9	19.9	134	3.3

Table 4.7: Log of Type I Protocol Tests (APS) – continued

Test no.	Date	Fluid Name	Surf.	Start Brix (degrees)	End Brix (degrees)	Fluid Temp (°C)	Fail Time (min)	AVG RATE (g/dm²/h)	Environment Canada Data			
									OAT (°C)	Wind Speed (km/h)	Wind Dir (degrees)	Visibility (km)
46	Jan-17-02	UCAR PG ADF	Box	24.0	9.0	60	15.8	3.1	-4.9	20.0	133	3.4
47	Jan-17-02	UCAR EG ADF	Box	19.8	7.0	60	15.3	3.1	-4.9	20.0	133	3.4
48	Jan-17-02	UCAR PG ADF	Plate	24.0	12.0	20	10.8	2.4	-5.0	19.4	132	3.5
49	Jan-17-02	UCAR EG ADF	Plate	19.8	6.0	20	10.5	2.5	-5.0	19.4	132	3.5
50	Jan-17-02	UCAR PG ADF (FFP -34°C)	Box	34.0	9.0	60	23.3	2.5	-4.9	21.6	124	1.9
51	Jan-17-02	UCAR PG ADF	Box	24.0	8.0	60	19.5	2.5	-4.9	21.6	126	1.9
52	Jan-17-02	UCAR EG ADF	Box	19.8	6.0	60	18.4	2.5	-4.9	21.6	126	1.9
53	Jan-17-02	UCAR PG ADF	Plate	24.0	11.0	20	10.9	2.6	-4.9	22.2	128	1.7
54	Jan-17-02	UCAR EG ADF	Plate	19.8	8.0	20	10.8	2.6	-4.9	22.1	128	1.7
55	Jan-17-02	UCAR ADF XL54	Box	33.0	7.0	60	21.1	3.0	-4.6	15.9	117	4.0
57	Jan-17-02	UCAR EG ADF	Box	19.8	7.0	60	18.0	2.7	-4.6	16.0	117	4.1
59	Jan-17-02	UCAR EG ADF	Plate	19.8	8.0	20	12.6	2.1	-4.6	16.1	117	4.3
60	Jan-17-02	UCAR PG ADF (FFP -34°C)	Box	34.0	1.0	60	10.2	12.5	-3.8	11.6	94	0.6
61	Jan-17-02	UCAR PG ADF	Box	22.8	0.5	60	9.8	12.7	-3.8	11.4	92	0.6
62	Jan-17-02	UCAR EG ADF	Box	19.3	0.5	60	9.2	12.7	-3.8	11.4	92	0.6
63	Jan-17-02	UCAR PG ADF	Plate	22.8	4.0	60	5.6	11.4	-3.8	11.4	94	0.6
64	Jan-17-02	UCAR EG ADF	Plate	19.3	3.0	20	5.5	11.3	-3.8	11.7	92	0.6
65	Jan-17-02	UCAR ADF XL54	Box	33.0	0.0	60	13.3	9.6	-3.2	7.9	81	0.9
66	Jan-17-02	UCAR PG ADF	Box	20.3	0.0	60	13.4	9.8	-3.2	7.9	81	0.9
67	Jan-17-02	UCAR EG ADF	Box	17.0	0.0	60	12.4	9.7	-3.2	7.9	81	0.9
68	Jan-17-02	UCAR PG ADF	Plate	20.3	2.3	20	7.1	9.5	-3.2	7.9	84	0.8
69	Jan-17-02	UCAR EG ADF	Plate	17.0	2.0	20	7.0	9.4	-3.2	7.9	84	0.8
70	Jan-17-02	UCAR ADF XL54	Box	33.0	3.0	60	15.9	4.2	-4.8	12.6	21	1.0
72	Jan-17-02	UCAR EG ADF	Box	17.0	3.0	60	14.4	4.0	-4.8	12.8	21	1.0
74	Jan-17-02	UCAR EG ADF	Plate	17.0	5.0	20	8.8	3.6	-4.7	12.2	23	1.0
75	Jan-17-02	UCAR ADF XL54	Box	33.0	7.3	60	9.8	9.1	-7.0	18.4	24	0.8
76	Jan-17-02	UCAR PG ADF	Box	25.0	8.5	60	9.5	9.4	-7.0	18.1	24	0.8
77	Jan-17-02	UCAR EG ADF	Box	20.5	7.5	60	9.7	9.8	-7.0	17.8	24	0.8
78	Jan-17-02	UCAR PG ADF	Plate	25.0	11.0	20	5.6	8.5	-7.0	17.9	24	0.8
79	Jan-17-02	UCAR EG ADF	Plate	20.5	7.0	20	7.0	8.7	-7.0	18.3	25	0.8
80	Jan-21-02	UCAR ADF XL54	Box	33.0	0.0	60	23.5	4.8	-1.4	6.0	10	1.3
81	Jan-21-02	UCAR PG ADF	Box	20.0	1.0	60	26.8	4.4	-1.4	6.0	10	1.3
82	Jan-21-02	UCAR EG ADF	Box	16.0	0.5	60	26.9	4.3	-1.4	6.0	10	1.3
83	Jan-21-02	UCAR PG ADF	Plate	20.0	4.5	20	10.7	4.8	-1.4	6.0	10	1.4
84	Jan-21-02	UCAR EG ADF	Plate	16.0	3.5	20	10.8	4.9	-1.4	6.0	10	1.4
85	Jan-21-02	UCAR PG ADF (FFP -34°C)	Box	34.0	3.0	60	33.5	2.1	-1.7	5.5	293	1.6
86	Jan-21-02	UCAR PG ADF	Box	20.0	2.5	60	30.5	2.2	-1.7	5.3	291	1.6
87	Jan-21-02	UCAR EG ADF	Box	16.0	2.5	60	28.1	2.2	-1.7	5.1	290	1.6
88	Jan-21-02	UCAR PG ADF	Plate	20.0	5.0	20	14.2	2.8	-1.7	4.9	293	1.6
89	Jan-21-02	UCAR EG ADF	Plate	16.0	3.5	20	14.6	2.8	-1.7	5.0	295	1.6
90	Jan-31-02	UCAR ADF XL54	Box	33.0	15.0	60	11.4	7.6	-13.8	25.8	34	1.2
91	Jan-31-02	UCAR PG ADF	Box	29.0	20.0	60	8.4	5.8	-13.8	25.6	33	1.2
92	Jan-31-02	UCAR EG ADF	Box	25.0	16.0	60	8.8	7.2	-13.8	25.6	34	1.2
93	Jan-31-02	UCAR PG ADF	Plate	29.0	21.0	20	5.0	5.1	-13.9	25.3	32	1.2
94	Jan-31-02	UCAR EG ADF	Plate	25.0	17.0	20	5.5	5.1	-13.9	25.4	33	1.2
95	Jan-31-02	UCAR PG ADF (FFP -34°C)	Box	34.0	20.0	60	12.9	5.1	-13.8	25.3	39	1.4
96	Jan-31-02	UCAR PG ADF	Box	29.0	19.0	60	10.5	5.0	-13.8	25.1	38	1.4
98	Jan-31-02	UCAR PG ADF	Plate	29.0	18.0	20	6.8	4.7	-13.8	25.2	38	1.4
100	Jan-31-02	UCAR ADF XL54	Box	34.0	20.0	60	15.8	3.9	-13.8	27.5	48	1.4
102	Jan-31-02	UCAR EG ADF	Box	25.0	16.0	60	10.7	3.9	-13.8	28.4	47	1.4
104	Jan-31-02	UCAR EG ADF	Plate	25.0	17.5	20	7.3	3.6	-13.8	29.2	47	1.4
105	Jan-31-02	UCAR PG ADF (FFP -34°C)	Box	33.7	21.0	60	18.0	4.1	-13.6	26.3	46	1.5
106	Jan-31-02	UCAR PG ADF	Box	30.0	21.0	60	12.2	4.7	-13.6	25.5	48	1.5
107	Jan-31-02	UCAR PG ADF	Plate	30.0	21.0	20	7.7	5.0	-13.6	24.9	48	1.4

Table 4.7: Log of Type I Protocol Tests (APS) – continued

Test no.	Date	Fluid Name	Surf.	Start Brix (degrees)	End Brix (degrees)	Fluid Temp (°C)	Fail Time (min)	AVG RATE (g/dm²/h)	Environment Canada Data			
									OAT (°C)	Wind Speed (km/h)	Wind Dir (degrees)	Visibility (km)
108	Feb-3-02	UCAR ADF XL54	Box	33.0	5.3	62	13.9	4.6	-9.1	7.9	89	1.9
109	Feb-3-02	UCAR EG ADF	Box	21.5	4.8	60	12.7	4.5	-9.1	7.9	89	1.9
110	Feb-3-02	UCAR EG ADF	Plate	21.8	6.8	20	9.7	4.2	-9.1	7.8	87	1.9
111	Feb-3-02	UCAR PG ADF (FFP -34°C)	Box	34.8	4.0	60	13.0	7.5	-8.1	11.4	106	1.1
112	Feb-3-02	UCAR PG ADF	Box	26.3	4.0	60	10.5	7.3	-8.1	11.4	106	1.1
114	Feb-3-02	UCAR PG ADF	Plate	26.3	8.0	20	7.3	7.2	-8.1	11.6	105	1.1
116	Feb-3-02	UCAR ADF XL54	Box	33.3	3.0	60	36.1	1.2	-5.3	13.3	82	2.6
118	Feb-3-02	UCAR EG ADF	Box	19.0	7.0	60	33.1	1.2	-5.3	13.1	82	2.6
120	Feb-3-02	UCAR EG ADF	Plate	19.0	5.8	20	18.0	1.4	-5.4	12.4	83	2.6
121	Feb-3-02	UCAR PG ADF (FFP -34°C)	Box	34.3	6.0	60	37.4	1.6	-4.5	13.4	59	2.8
122	Feb-3-02	UCAR PG ADF	Box	22.8	7.0	60	37.3	1.6	-4.5	13.4	59	2.8
123	Feb-3-02	UCAR PG ADF	Plate	22.8	7.0	20	28.0	0.9	-4.5	13.0	60	3.0
124	Feb-3-02	UCAR ADF XL54	Box	33.3	7.0	60	16.4	4.1	-7.2	19.1	26	1.4
125	Feb-3-02	UCAR EG ADF	Box	19.0	6.0	60	12.5	3.3	-7.3	19.0	25	1.4
126	Feb-3-02	UCAR EG ADF	Plate	19.0	8.0	20	8.6	3.4	-7.2	18.7	26	1.4
127	Feb-3-02	UCAR PG ADF (FFP -34°C)	Box	34.0	11.0	60	14.7	4.7	-8.2	15.7	20	1.4
129	Feb-3-02	UCAR PG ADF	Box	27.3	12.0	60	13.8	4.9	-8.2	15.8	20	1.4
131	Feb-3-02	UCAR PG ADF	Plate	27.3	13.0	20	8.8	4.7	-8.2	15.9	22	1.4
132	Feb-3-02	UCAR ADF XL54	Box	33.0	10.0	60	12.9	4.7	-8.6	14.2	16	1.1
133	Feb-3-02	UCAR PG ADF	Box	27.2	13.0	60	9.3	5.5	-8.6	14.3	17	1.1
134	Feb-3-02	UCAR EG ADF	Box	22.0	9.5	60	10.3	4.9	-8.6	14.5	17	1.1
135	Feb-3-02	UCAR PG ADF	Plate	27.2	15.0	20	7.0	5.6	-8.6	14.4	19	1.1
136	Feb-3-02	UCAR EG ADF	Plate	22.0	11.0	20	7.1	5.3	-8.6	14.4	19	1.1
137	Feb-3-02	UCAR ADF XL54	Box	33.0	8.5	60	9.3	7.7	-9.2	12.6	80	0.8
138	Feb-3-02	UCAR PG ADF	Box	27.5	10.5	60	8.0	7.7	-9.2	12.6	50	0.8
139	Feb-3-02	UCAR EG ADF	Box	22.3	7.8	60	7.7	7.6	-9.2	12.5	54	0.8
140	Feb-3-02	UCAR PG ADF	Plate	27.5	11.3	20	4.9	7.8	-9.2	13.0	12	0.8
141	Feb-3-02	UCAR EG ADF	Plate	22.3	12.3	20	5.6	7.6	-9.2	12.7	10	0.8
142	Feb-10-02	UCAR ADF XL54	Box	33.0	5.5	60	19.2	16.1	-2.8	43.2	20	1.1
143	Feb-10-02	UCAR PG ADF	Box	21.5	9.0	60	16.6	16.8	-2.8	43.0	19	1.1
144	Feb-10-02	UCAR EG ADF	Box	17.0	5.0	60	13.7	17.7	-2.8	42.1	20	1.1
145	Feb-10-02	UCAR PG ADF	Plate	21.5	8.3	20	9.3	20.2	-2.7	40.9	21	1.1
146	Feb-10-02	UCAR EG ADF	Plate	17.0	7.0	20	7.5	22.5	-2.8	41.0	20	1.1
150	Feb-10-02	UCAR PG ADF	Plate	23.0	11.0	20	4.9	20.1	-4.7	47.5	13	0.6
152	Feb-10-02	UCAR ADF XL54	Box	33.0	10.5	60	52.4	2.0	-5.6	29.5	17	3.3
153	Feb-10-02	UCAR EG ADF	Box	19.0	10.3	60	49.0	2.0	-5.6	29.8	17	3.3
154	Feb-10-02	UCAR EG ADF	Plate	19.0	9.8	20	20.8	1.8	-5.5	32.9	16	2.4
155	Feb-10-02	UCAR PG ADF	Plate	25.0	14.0	20	12.3	2.9	-6.1	22.5	302	1.9
156	March-18-02	UCAR ADF XL54	Box	33.8	0.0	60	19.1	15.8	-0.7	21.2	95	0.7
157	March-18-02	UCAR PG ADF	Box	20.8	0.0	62	16.6	15.6	-0.7	21.4	95	0.7
158	March-18-02	UCAR PG ADF	Plate	19.0	2.0	20	7.8	14.3	-0.8	21.1	93	0.6
159	March-18-02	UCAR EG ADF	Plate	17.3	1.0	20	8.3	14.8	-0.8	21.3	94	0.6
161	March-18-02	UCAR ADF XL54	Box	34.0	0.0	60	8.8	35.8	-0.5	26.1	109	0.5
162	March-18-02	UCAR PG ADF	Box	19.0	0.0	60	9.4	33.2	-0.5	25.4	109	0.5
163	March-18-02	UCAR EG ADF	Box	17.3	0.0	60	9.7	31.6	-0.5	24.7	110	0.5
164	March-18-02	UCAR PG ADF	Plate	19.0	1.0	20	5.6	32.8	-0.5	25.4	110	0.5
165	March-18-02	UCAR EG ADF	Plate	17.3	0.5	20	5.3	30.8	-0.5	25.0	110	0.5
167	March-18-02	UCAR ADF XL54	Box	34.0	0.5	60	6.7	40.5	-0.5	22.0	101	0.5
168	March-18-02	UCAR PG ADF	Box	20.5	0.0	60	9.4	41.9	-0.5	20.9	102	0.5
169	March-18-02	UCAR EG ADF	Box	17.0	0.0	60	6.3	42.4	-0.5	21.7	101	0.5
170	March-18-02	UCAR PG ADF	Plate	34.0	0.0	20	3.5	41.6	-0.5	23.2	104	0.5
171	March-18-02	UCAR EG ADF	Plate	20.5	1.0	20	3.5	42.5	-0.5	23.2	104	0.5
173	March-18-02	UCAR ADF XL54	Box	33.5	1.0	60	10.7	25.9	-0.7	26.0	90	N/A
174	March-18-02	UCAR PG ADF	Box	20.3	3.8	60	11.2	26.8	-0.7	26.0	90	N/A
175	March-18-02	UCAR EG ADF	Box	16.5	1.0	60	11.7	27.5	-0.7	26.0	90	N/A
176	March-18-02	UCAR PG ADF	Plate	20.3	1.8	20	6.1	26.5	-0.7	26.0	90	N/A

Table 4.7: Log of Type I Protocol Tests (APS) – continued

Test no.	Date	Fluid Name	Surf.	Start Brix (degrees)	End Brix (degrees)	Fluid Temp (°C)	Fail Time (min)	AVG RATE ($g/dm^2/h$)	Environment Canada Data			
									OAT (°C)	Wind Speed (km/h)	Wind Dir (degrees)	Visibility (km)
177	March-18-02	UCAR EG ADF	Plate	16.5	2.0	20	6.5	28.4	-0.7	26.0	90	N/A
178	March-18-02	UCAR ADF XL54	Box	34.2	0.0	60	7.7	33.4	-0.6	26.0	90	N/A
179	March-18-02	UCAR PG ADF	Box	21.0	0.5	60	6.9	33.0	-0.6	26.0	90	N/A
180	March-18-02	UCAR EG ADF	Box	15.3	0.5	58	6.8	34.3	-0.6	26.0	90	N/A
181	March-18-02	UCAR PG ADF	Plate	21.5	2.3	20	4.3	31.5	-0.6	26.0	90	N/A
182	March-18-02	UCAR EG ADF	Plate	16.8	1.8	20	4.0	32.9	-0.6	26.0	90	N/A
185	March-18-02	UCAR ADF XL54	Box	33.8	0.8	60	11.1	21.9	-0.6	26.0	90	N/A
186	March-18-02	UCAR PG ADF	Box	21.5	0.0	62	10.8	21.8	-0.6	26.0	90	N/A
187	March-18-02	UCAR EG ADF	Box	16.3	0.5	62	10.7	21.7	-0.6	26.0	90	N/A
188	March-18-02	UCAR PG ADF	Plate	21.5	3.0	18	5.5	21.9	-0.6	26.0	90	N/A
189	March-18-02	UCAR EG ADF	Plate	16.8	2.0	18	6.2	21.5	-0.6	26.0	90	N/A
191	March-18-02	UCAR ADF XL54	Box	34.0	0.0	63	10.5	22.4	-0.8	26.0	90	N/A
192	March-18-02	UCAR PG ADF	Box	21.3	0.8	60	10.3	21.7	-0.8	26.0	90	N/A
193	March-18-02	UCAR EG ADF	Box	16.8	1.0	62	10.3	21.0	-0.8	26.0	90	N/A
194	March-18-02	UCAR PG ADF	Plate	21.3	3.0	17	5.8	22.9	-0.8	26.0	90	N/A
195	March-18-02	UCAR EG ADF	Plate	16.8	2.3	17	5.5	22.0	-0.8	26.0	110	N/A
196	March-18-02	UCAR ADF XL54	Box	34.8	1.0	62	12.0	21.1	-0.9	31.8	110	0.8
197	March-18-02	UCAR PG ADF	Box	21.8	1.0	62	10.9	20.9	-0.9	31.5	110	0.8
198	March-18-02	UCAR EG ADF	Box	16.0	1.0	62	10.2	20.8	-0.9	31.5	110	0.8
199	March-18-02	UCAR PG ADF	Plate	21.3	3.3	19	6.3	16.3	-0.9	30.6	108	0.8
200	March-18-02	UCAR EG ADF	Plate	16.0	3.5	19	6.2	16.3	-0.9	30.2	109	0.8
201	March-18-02	UCAR PG ADF	Plate	21.5	3.0	20	3.5	36.8	-0.9	32.9	111	0.8
203	March-18-02	UCAR ADF XL54	Box	33.8	0.5	62	7.0	31.5	-1.0	32.6	113	0.5
204	March-18-02	UCAR PG ADF	Box	21.5	1.0	62	6.6	31.1	-1.0	32.8	113	0.5
205	March-18-02	UCAR EG ADF	Box	16.3	0.3	62	6.7	30.3	-1.0	32.9	113	0.5
206	March-18-02	UCAR PG ADF	Plate	21.5	3.0	19	3.5	31.3	-1.0	32.6	113	0.5
207	March-18-02	UCAR EG ADF	Plate	15.8	3.0	19	3.1	30.5	-1.0	33.3	114	0.5
208	March-18-02	UCAR ADF XL54	Box	34.3	1.5	63	9.8	20.8	-1.2	30.3	116	0.7
209	March-18-02	UCAR PG ADF	Box	21.5	1.3	60	9.5	20.5	-1.2	30.3	116	0.7
210	March-18-02	UCAR EG ADF	Box	16.5	1.0	61	9.1	20.2	-1.2	30.4	116	0.7
211	March-18-02	UCAR PG ADF	Plate	21.5	4.3	20	4.7	21.3	-1.2	30.0	116	0.8
212	March-18-02	UCAR EG ADF	Plate	16.0	3.3	20	4.8	20.5	-1.2	30.2	116	0.8
214	March-20-02	UCAR ADF XL54	Box	N/A	N/A	60	5.6	60.3	0.3	28.8	143	0.4
215	March-20-02	UCAR PG ADF	Box	N/A	N/A	60	5.5	60.2	0.3	29.0	142	0.4
216	March-20-02	UCAR EG ADF	Box	N/A	N/A	60	5.4	60.0	0.2	29.0	140	0.4
217	March-20-02	UCAR PG ADF	Plate	N/A	1.0	20	2.7	60.5	0.3	29.6	141	0.4
218	March-20-02	UCAR EG ADF	Plate	N/A	0.5	20	2.7	60.2	0.2	30.1	140	0.4
219	March-20-02	UCAR ADF XL54	Box	N/A	0.0	60	7.4	33.3	0.2	20.4	138	0.3
220	March-20-02	UCAR PG ADF	Box	N/A	0.0	60	8.0	29.2	0.2	20.0	138	0.3
221	March-20-02	UCAR EG ADF	Box	N/A	0.0	60	8.5	34.6	0.2	20.0	138	0.3
222	March-20-02	UCAR PG ADF	Plate	N/A	0.5	20	4.0	33.0	0.2	20.0	137	0.3
223	March-20-02	UCAR EG ADF	Plate	N/A	0.5	20	4.1	34.0	0.2	20.0	137	0.3
224	March-20-02	UCAR ADF XL54	Box	35.0	0.0	62	9.0	31.2	0.3	16.9	138	0.5
226	March-20-02	UCAR EG ADF	Box	15.0	0.0	60	9.5	31.9	0.3	16.8	138	0.5
228	March-20-02	UCAR EG ADF	Plate	14.3	0.0	20	4.9	31.2	0.3	15.7	139	0.5
229	March-20-02	UCAR ADF XL54	Box	34.8	0.0	61	12.4	21.6	0.3	22.4	155	1.1
230	March-20-02	UCAR PG ADF	Box	21.5	0.0	60	10.8	21.6	0.3	22.1	155	1.1
231	March-20-02	UCAR EG ADF	Box	14.5	0.0	60	12.2	21.8	0.3	22.7	155	1.1
232	March-20-02	UCAR PG ADF	Plate	20.5	2.0	20	4.6	21.0	0.4	21.0	154	1.1
233	March-20-02	UCAR EG ADF	Plate	14.5	1.0	20	4.8	21.4	0.3	21.0	154	1.1
234	March-21-02	UCAR ADF XL54	Box	33.5	0.0	60	18.2	13.9	-0.2	17.5	132	0.6
235	March-21-02	UCAR PG ADF	Box	19.0	0.0	62	21.0	12.9	-0.2	17.6	132	0.6
236	March-21-02	UCAR EG ADF	Box	14.5	0.0	61	21.2	12.6	-0.2	17.5	132	0.6
237	March-21-02	UCAR PG ADF	Plate	17.8	0.0	20	6.5	15.5	-0.2	16.7	134	0.6
238	March-21-02	UCAR EG ADF	Plate	14.3	1.0	20	7.2	15.2	-0.2	16.9	134	0.6

N/A – Data not available.

4.4.2 Plotting of Endurance Time Data – APS Tests

These tests were charted for each fluid, concentration, and test surface, according to Table 4.6. These charts are presented in Figure 4.4 to Figure 4.9, and show the data split by HOT table temperature ranges, with the upper and lower limits for moderate snowfall rates identified at 25 and 10 g/dm²/h.

4.4.3 Plotting of Fluid Freeze Point and Temperature Data – APS Tests

As mentioned in Subsection 4.3.2, fluid dilution measurements were conducted on the test surfaces. Figure 4.10 and Figure 4.11 illustrate the surface temperatures and fluid freeze point mechanisms that influenced fluid failure. The test surface temperature profile curves are shown. The curves gradually approach an ultimate value, ambient temperature. The fluid freeze point temperature curve was derived from a number of fluid concentration (Brix) values measured progressively during testing in precipitation conditions. This curve represents the fluid freeze point temperature as the fluid gradually diluted, increasing from its initial value toward an ultimate value.

In summary, both curves represent temperature profiles. One curve represents the surface temperature decay rate profile and the other represents the temperature profile of the freezing point of the fluid. The point where the two curves coincide is the expected endurance time in actual operations. In other words, when the fluid is applied, freezing is expected to occur when the fluid freeze point and the surface temperature match.

The data displayed in Figure 4.10 shows the surface temperature decay profiles for the empty aluminum box and the regular endurance time plate for two tests run on January 31, 2002. The temperature peak is much higher for the empty aluminum box, as the fluid was applied at 60°C, whereas the fluid application temperature was 20°C for the regular plate. The empty aluminum box holds its temperature longer than the plate, primarily due to its geometry and insulation. The outcome is a smoother temperature profile curve and subsequently a longer endurance time.

Fluid freeze point temperatures were also charted over time as the fluid progressively diluted under precipitation, as shown in Figure 4.10. For about 90 seconds right after pouring, the dilution curve of the empty aluminum box presents a slight "enrichment". That is, for a short period of time after pouring, water evaporates from the heated fluid, increasing the glycol concentration of the aqueous solution. A few observations are noteworthy concerning this enrichment.

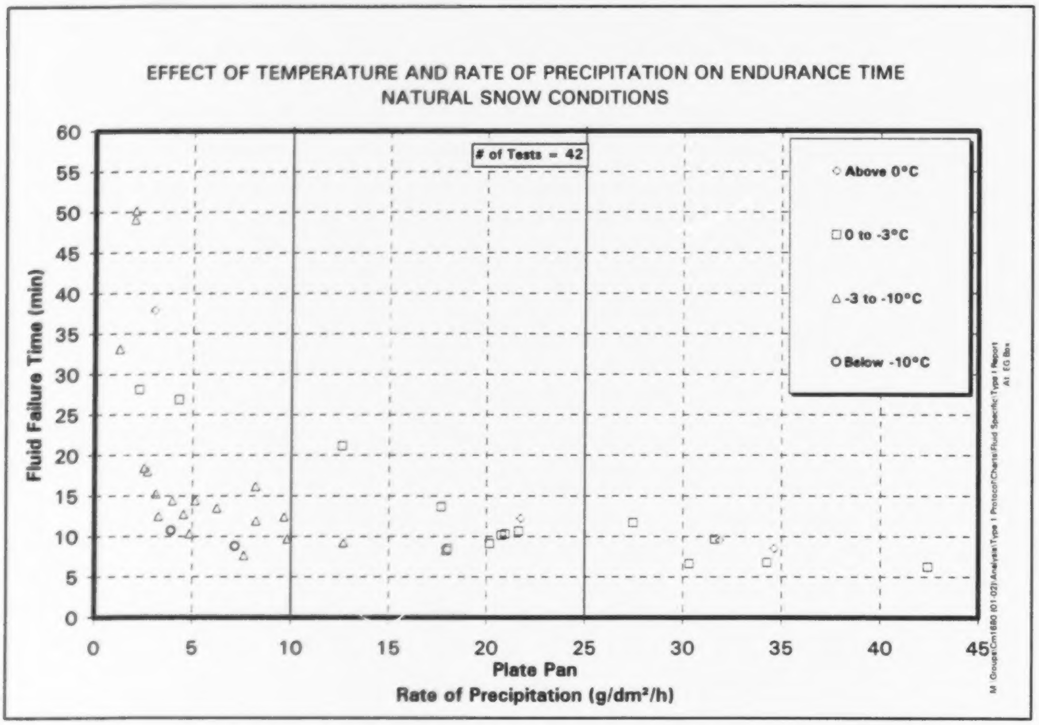

Figure 4.4: UCAR EG ADF (10° Buffer) on Boxes – APS Data

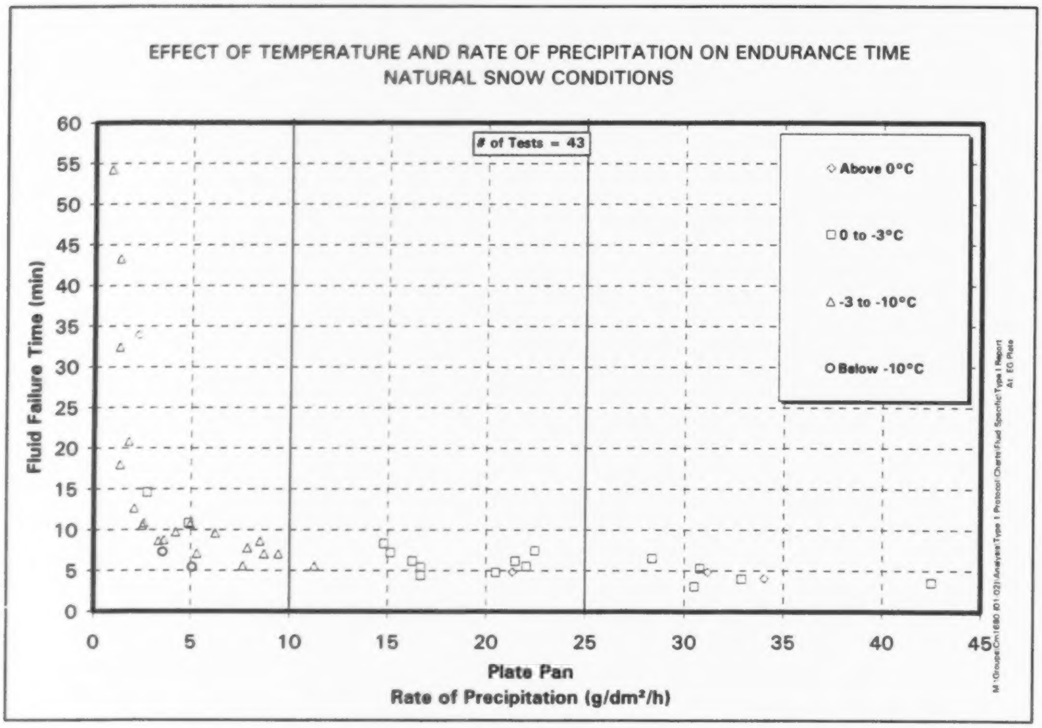

Figure 4.5: UCAR EG ADF (10° Buffer) on Plates – APS Data

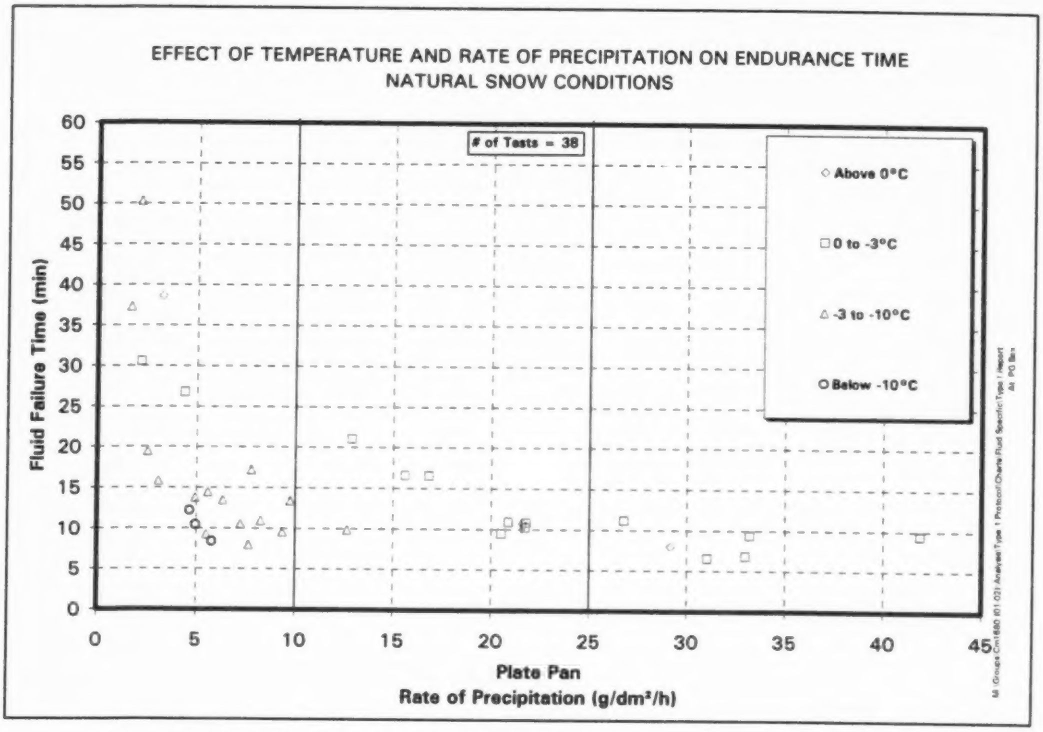

Figure 4.6: UCAR PG ADF (10° Buffer) on Boxes – APS Data

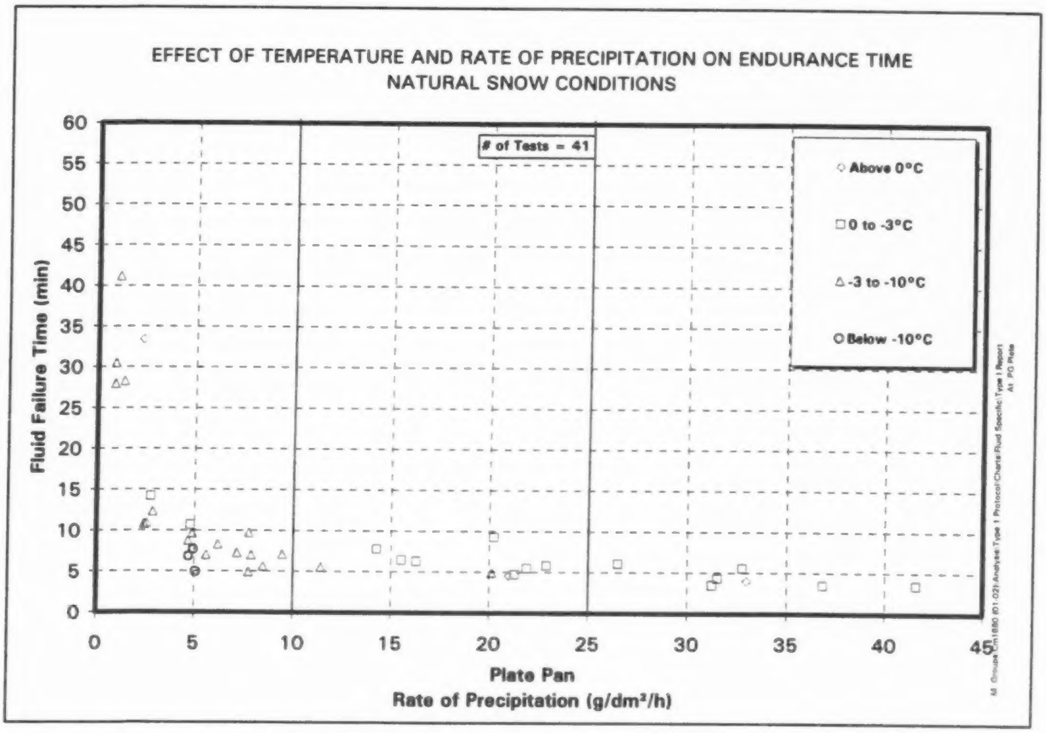

Figure 4.7: UCAR PG ADF (10° Buffer) on Plates – APS Data

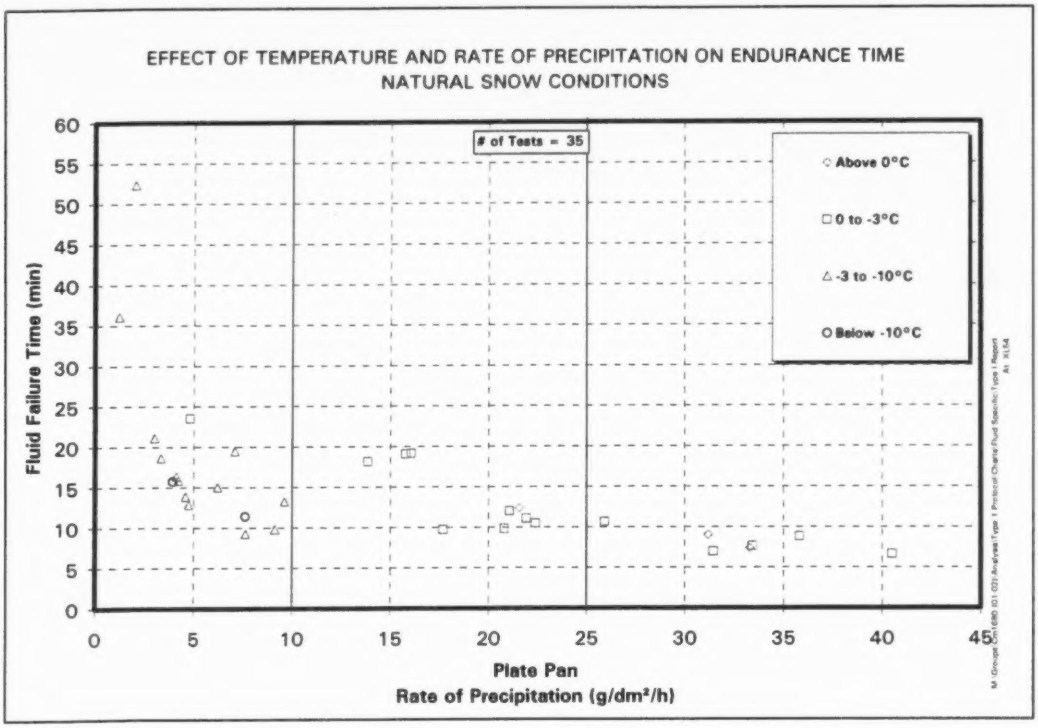

Figure 4.8: UCAR ADF XL54 on Boxes – APS Data

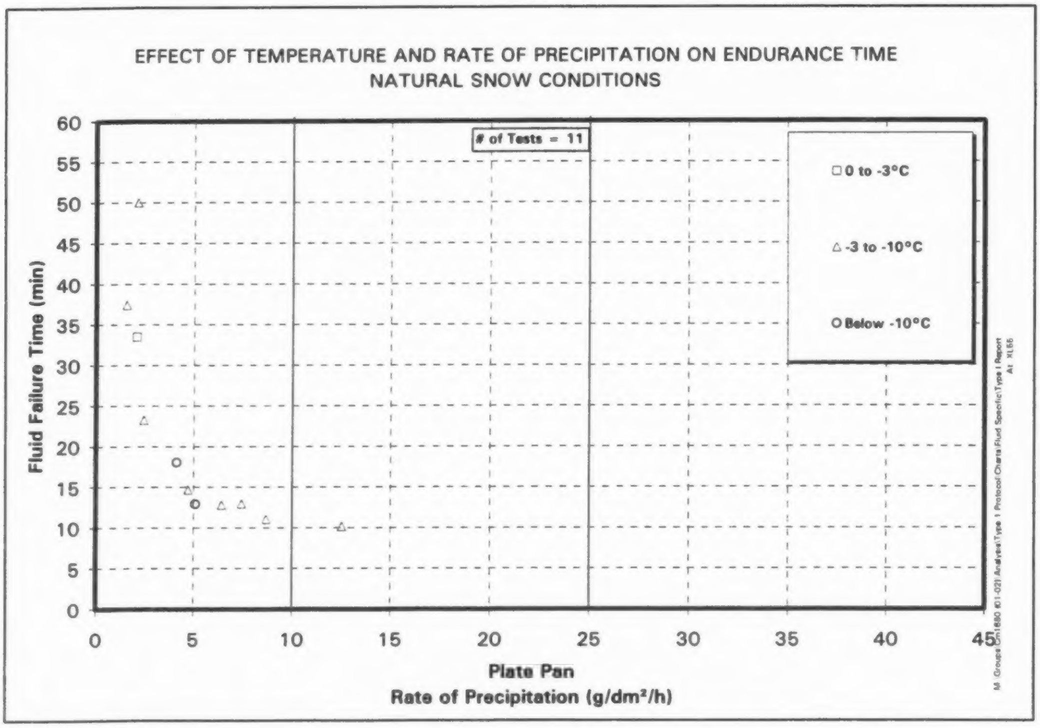

Figure 4.9: UCAR PG ADF (FFP -34°C) on Boxes – APS Data

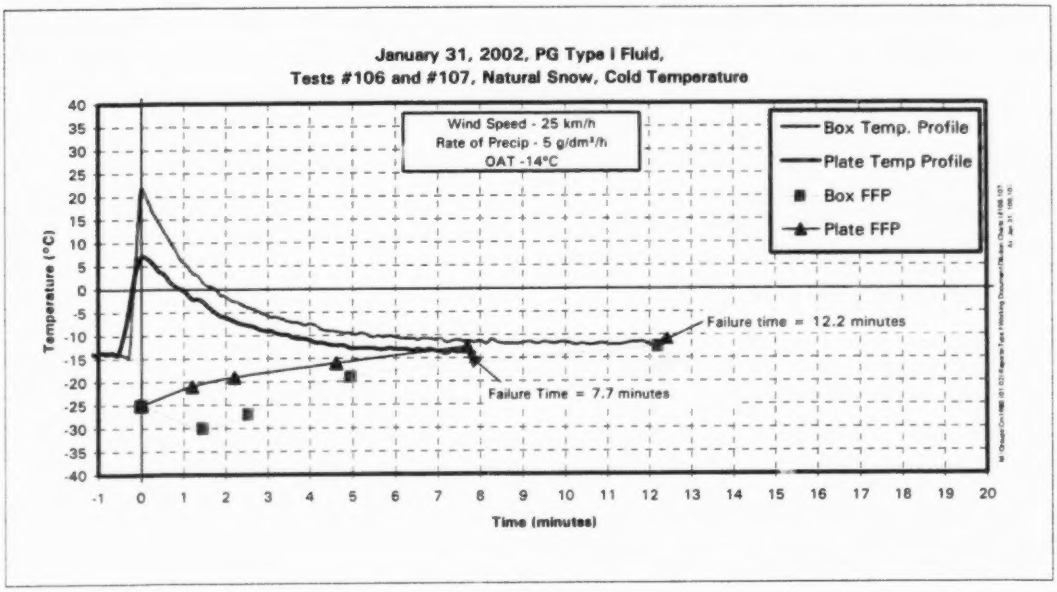

Figure 4.10: Surface Temperature Profiles and Fluid Dilution, January 31, 2002

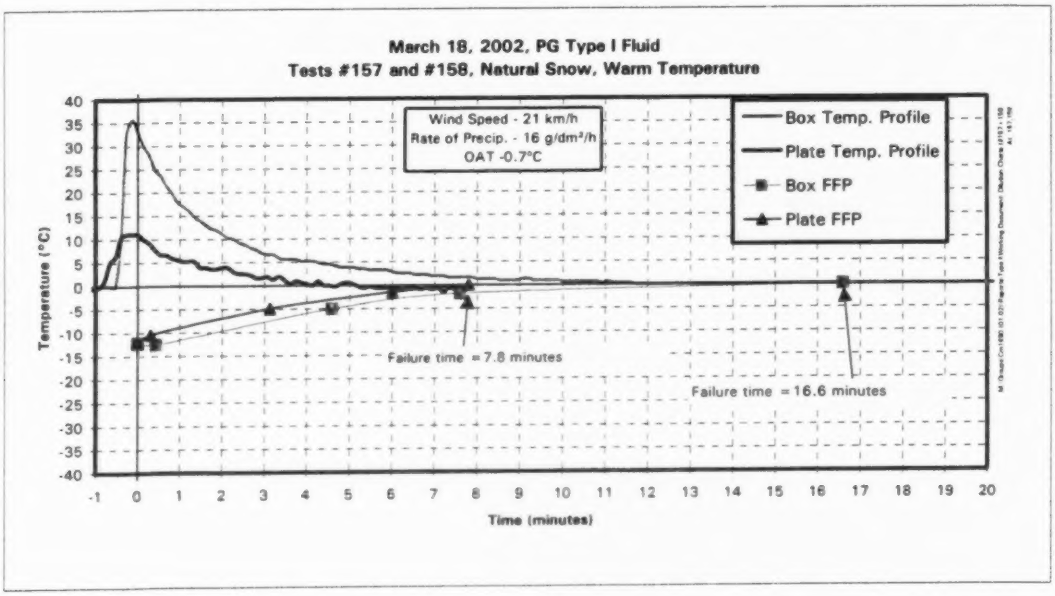

Figure 4.11: Surface Temperature Profiles and Fluid Dilution, March 18, 2002

a) Fluid mixed to a 10°C buffer has better enrichment than standard mix fluid;

b) Fluid mixed to freeze point of -15°C has little to no enrichment; and

c) Fluid enrichment may affect results in some conditions:

- Low precipitation rates;
- Medium cold temperatures; and
- High wind speeds.

Similar results are presented in Figure 4.11, which shows a snowstorm on another day, March 18, 2002. In this case, the fluid "enrichment" at the beginning of the test was significantly reduced. The rate of precipitation was about three times higher on this day than on January 31, which showed that the water evaporation was reduced and thus did not increase the glycol concentration.

The entire set of charts for each test is included in Appendix K.

4.4.4 Evaluation of Endurance Time vs. Protection Time

In some cases during testing, it was observed that after a short while following fluid failure, the contamination adhered to the surface. Regarding this phenomenon, the following observations can be made:

a) Fluid failures where the fluid has diluted to water prior to the plate temperature dropping below 0°C can result in adherence. At milder temperatures (-3°C and above), heated fluid is more likely to dilute to water prior to the surface temperature dropping below 0°C. This is particularly true in the case of application of the heated fluid onto the empty aluminum box. Surface protection was being provided by heat in these cases. When freezing finally occurred, the resulting ice adhered to the surface, as illustrated in Figure 4.12;

b) Fluid failures experienced when the fluid still had some strength and the plate temperature was below 0°C, did not present adherence. The protection was provided by the existing glycol concentration on the test surface; and

c) In snow at colder temperatures and lower precipitation rates, when the test surface was exposed far beyond the time when failure was called, the final fluid concentration did not dilute beyond a Brix value of 4 or 5 (-2 to -2.5°C). The failed fluid had the aspect and consistency of slush. In these cases, the visually failed fluid did not adhere.

The presence of adherence in Figure 4.12 was observed but not recorded on the data forms, but for about 4 minutes before failure there was water on the test surface and the surface protection was provided by heat exclusively. This is a typical case where adherence could occur.

A similar scenario could take place at outside air temperatures just above 0°C, where radiation could drive the surface temperature below 0°C. This is primarily true during night time, when the sky radiation is more likely to cool down the surface temperature below ambient temperature.

Figure 4.13 illustrates a case with no adherence for over 20 minutes after fluid failure.

The question arises as to why the freeze point remains constant for more than 20 minutes while the rate of precipitation is still falling. One possible explanation for this behaviour is the capillary action of snowflakes. This phenomenon is described further in TC report TP 13484E, *Characteristics of Failure of Aircraft Anti-Icing Fluids Subjected to Precipitation* (6).

Another possibility is that the glycol-water solution that was present after failure was called will not solidify completely. Only a "slush" solution is present, and the fact that it will not solidify is a physical characteristic of glycol at the temperatures in question. So why does the falling snow not dilute the fluid further? It is believed that there are two scenarios. The first scenario is illustrated in Test #168. In this case, the wind forces were high (20.9 km/h), causing the snow to blow away from the upper layers of the contamination. In the second scenario, where there is low air velocity, the snow may accumulate over the surface, but not penetrate the interface between the plate and solution, due to the capillary forces. In both scenarios, the solution will not adhere.

During freezing drizzle and freezing rain conditions, Type I fluids have been observed adhering to the plate approximately 1 minute after failure. This short time does not provide a large safety window for aircraft take-off.

4.4.5 Comparison of Endurance Times Between Plate and Box – APS Data

To quantify the results obtained using the new test protocol, APS conducted endurance time tests on empty aluminum boxes and used plates for comparison purposes. The results are illustrated in Figure 4.14 and Figure 4.15 for UCAR EG ADF and UCAR PG ADF, respectively. These charts show the endurance time difference between the regular ET plate and the empty aluminum box. Each adjacent pair of bars represents two tests conducted at the same time on a

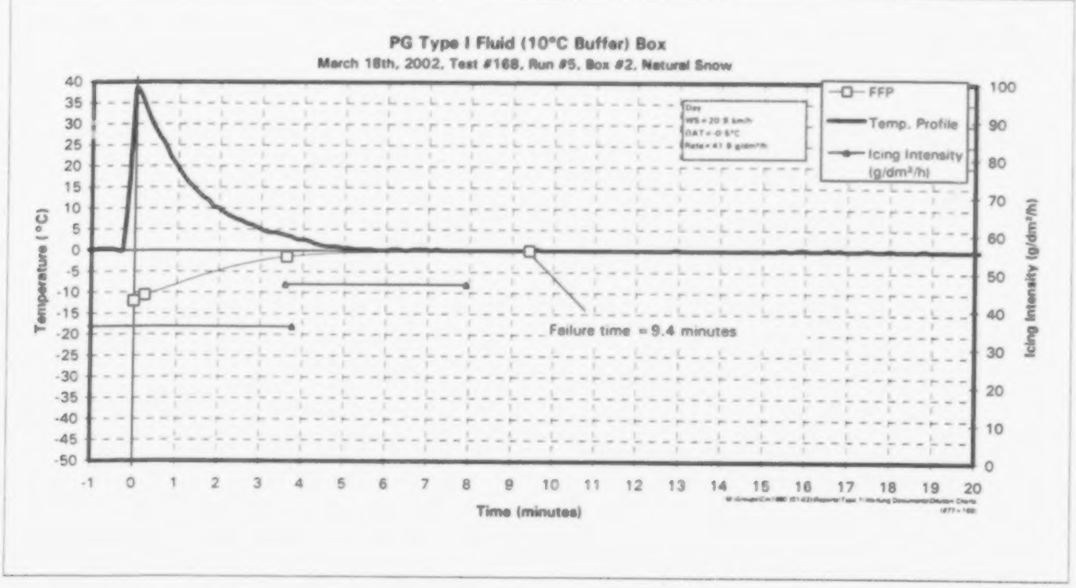

Figure 4.12: Surface Temperature Profile and Fluid Dilution, March 18, 2002

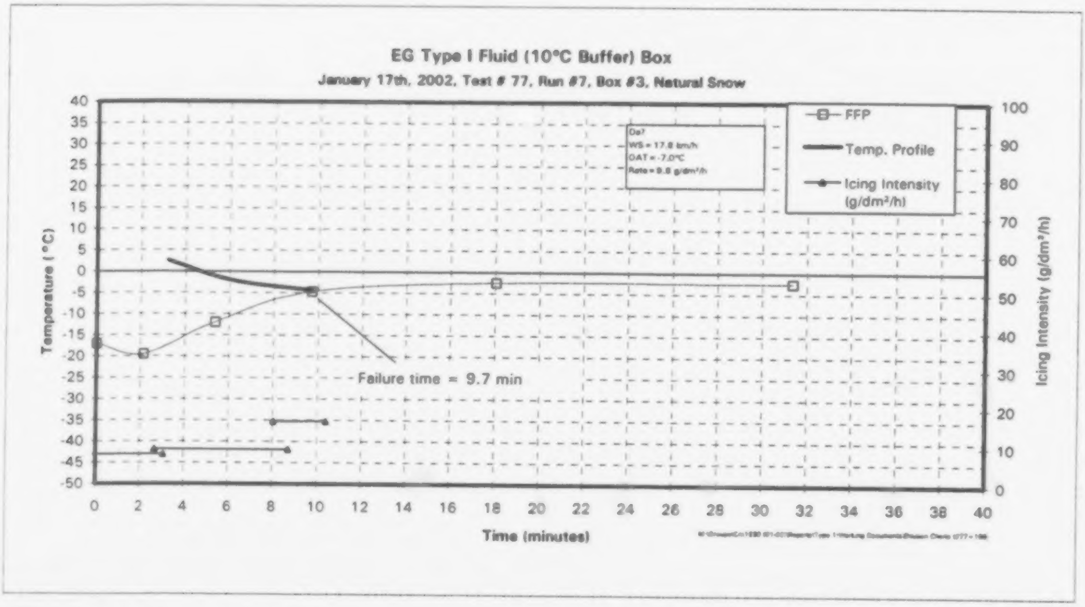

Figure 4.13: Surface Temperature Profile and Fluid Dilution, January 17, 2002

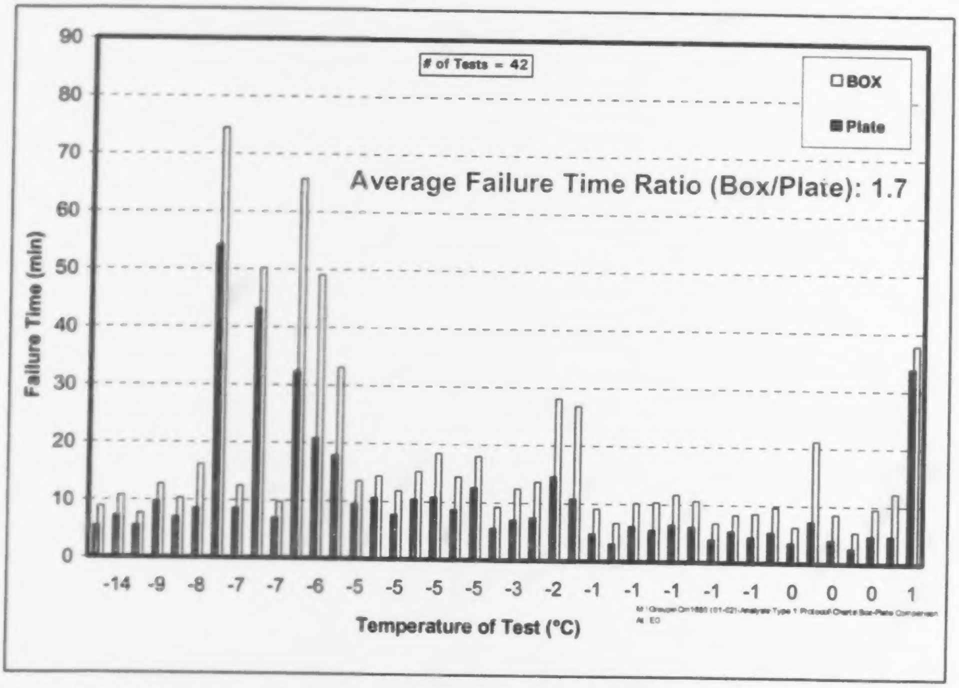

Figure 4.14: Type I EG Fluids – Comparison of Failure Time Between Plate and Box

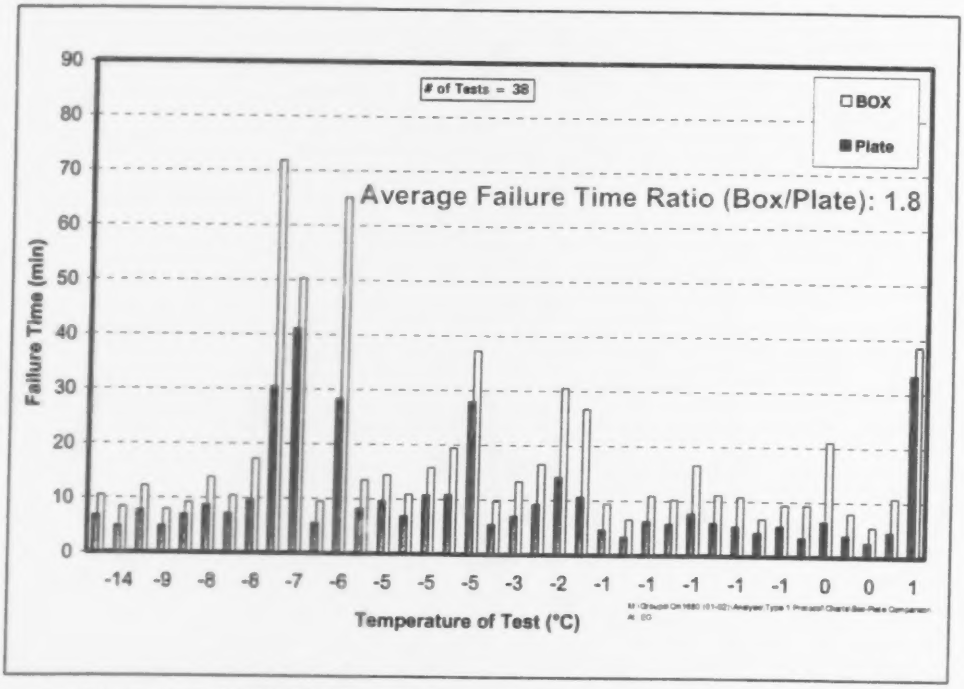

Figure 4.15: Type I PG Fluids – Comparison of Failure Time Between Plate and Box

plate and on a box. As observed on the charts, the endurance times obtained using the newly developed Type I protocol were on average 70 to 80 percent higher than those developed using the regular HOT plate

4.4.6 AMIL Results

AMIL conducted endurance time tests using the new Type I protocol on the roof of the university in Chicoutimi, Quebec.

Three fluids were tested: UCAR EG ADF, UCAR PG ADF, and Octagon Octaflo EF. These tests were done exclusively on boxes and included different fluid concentrations. Table 4.8 provides a summary of tests performed by AMIL.

Table 4.8: Summary of AMIL Endurance Time Tests Using the New Type I Protocol

Fluid Name	Number of Tests
UCAR EG ADF	35
UCAR PG ADF	39
Octagon Octaflo EF	39
UCAR ADF XL54	37
Octagon Octaflo EF Premix	30

A summary of the conditions for tests conducted by AMIL during the winter of 2001-02 is presented below:

a) 18 snow events;
b) 180 tests;
c) Snowfall rate between 0.8 and 27.2 g/dm²/h;
d) Temperature between -3.1 and -15.1°C; and
e) Wind speed between 0 and 28 km/h.

A complete log of tests, as provided by AMIL, is presented in Table 4.9.

The test results have been plotted for each individual fluid and are presented in Figures 4.16 to 4.20.

Table 4.9: Log of Type I Protocol Tests (AMIL)

# Test	Fluid	T_{air} (°C)	Intensity ($g/dm^2/h$)	Wind speed (km/h)	Failure*
OS2001(4)	Octagon Octaflo EF	-3.6 ± 0.03	3.95	5 to 9	14 min 15 s
OS2001(4)	Octagon Octaflo EF	-3.7 ± 0.03	3.47	5 to 9	14 min 55 s
OS2002(4)	Octagon Octaflo EF	-3.7 ± 0.06	1.94	13	23 min 15 s
OS2002(4)	Octagon Octaflo EF	-3.7 ± 0.06	1.94	13	20 min 52 s
OS2003(4)	Octagon Octaflo EF	-10.0 ± 0.02	1.15	10 to 15	11 min 40 s
OS2003(4)	Octagon Octaflo EF	-10.0 ± 0.02	1.15	10 to 15	10 min 46 s
OS2005(2)	Octagon Octaflo EF	-4.5 ± 0.71	8.43	0	11 min 55 s
OS2005(2)	Octagon Octaflo EF	-4.5 ± 0.71	8.43	0	11 min 55 s
OS2007(3) (no spreader)	Octagon Octaflo EF	-6.8 ± 0.04	3.25	10 to 15	14 min 45 s
OS2007(3)	Octagon Octaflo EF	-6.8 ± 0.04	3.25	10 to 15	12 min 07 s
OS2008(2)	Octagon Octaflo EF	-4.5 ± 0.02	15.60	0 to 5	6 min 30 s
OS2008(2)	Octagon Octaflo EF	-4.5 ± 0.03	15.60	0 to 5	7 min 44 s
OS2010(2)	Octagon Octaflo EF	-11.5 ± 0.20	1.00	10	17 min 21 s
OS2011(1)	Octagon Octaflo EF	-10.8 ± 0.05	4.24	14	13 min 09 s
OS2011(1)	Octagon Octaflo EF	-10.8 ± 0.06	4.59	14	12 min 15 s
OS2015(2)	Octagon Octaflo EF	-7.7 ± 0.03	12.08	0 to 8.6	6 min 22 s
OS2015(2)	Octagon Octaflo EF	-7.6 ± 0.06	12.08	0 to 8.6	7 min 12 s
OS2015(5)	Octagon Octaflo EF	-6.6 ± 0.39	8.12	0 to 8.6	9 min 28 s
OS2015(5)	Octagon Octaflo EF	-6.6 ± 0.30	8.12	0 to 8.6	9 min 51 s
OS2015(8)	Octagon Octaflo EF	-7.6 ± 0.06	9.04	10 to 15	6 min 10 s
OS2015(8)	Octagon Octaflo EF	-7.7 ± 0.07	11.28	10 to 15	7 min 41 s
OS2015(11)	Octagon Octaflo EF	-8.3 ± 0.09	7.96	10 to 15	7 min 28 s
OS2015(11)	Octagon Octaflo EF	-8.4 ± 0.07	7.96	10 to 15	6 min 54 s
OS2015(14)	Octagon Octaflo EF	-9.7 ± 0.07	5.08	15 to 20	8 min 34 s
OS2015(14)	Octagon Octaflo EF	-9.7 ± 0.07	5.08	15 to 20	8 min 47 s
OS2016(3)	Octagon Octaflo EF	-9.0	2.98	± 16	16 min 20 s
OS2016(3)	Octagon Octaflo EF	-9.0	2.98	± 16	15 min 50 s
OS2017(1)	Octagon Octaflo EF	-7.8 ± 0.04	3.12	11	16 min 00 s
OS2017(1)	Octagon Octaflo EF	-7.8 ± 0.03	3.31	11	11 min 07 s
OS2018(4) (with thermos)	Octagon Octaflo EF	-10.7 ± 0.03	12.72	30	6 min 35 s
OS2018(4)	Octagon Octaflo EF	-10.7 ± 0.03	12.72	30	6 min 18 s
OS2018(9) (with thermos)	Octagon Octaflo EF	-11.2 ± 0.01	17.96	24 to 40	6 min 39 s
OS2018(9)	Octagon Octaflo EF	-11.2 ± 0.02	17.96	24 to 40	5 min 47 s
OS2019(4)	Octagon Octaflo EF	-11.4 ± 0.02	6.44	15 to 25	7 min 43 s
OS2019(4)	Octagon Octaflo EF	-11.4 ± 0.03	4.28	15 to 25	8 min 02 s
OS2019(9)	Octagon Octaflo EF	-12.0 ± 0.02	22.80	20 to 40	3 min 45 s
OS2019(9)	Octagon Octaflo EF	-12.0 ± 0.03	22.80	20 to 40	3 min 13 s
OS2019(14)	Octagon Octaflo EF	-12.0 ± 0.02	23.84	20 to 30	3 min 43 s
OS2019(14)	Octagon Octaflo EF	-12.0 ± 0.01	25.12	20 to 30	3 min 11 s
OS2001(2)	UCAR EG ADF	-3.4 ± 0.04	5.07	5 to 9	14 min 00 s
OS2001(2)	UCAR EG ADF	-3.5 ± 0.03	4.93	5 to 9	12 min 07 s
OS2001(6)	UCAR EG ADF	-3.8 ± 0.01	1.20	7	28 min 53 s
OS2002(2)	UCAR EG ADF	-3.4 ± 0.10	2.66	5	16 min 14 s
OS2002(2)	UCAR EG ADF	-3.4 ± 0.08	2.66	5	18 min 02 s
OS2003(2)	UCAR EG ADF	-9.9 ± 0.03	5.04	10 to 15	7 min 55 s

Table 4.9: Log of Type I Protocol Tests (AMIL) – continued

# Test	Fluid	T_{air} (°C)	Intensity ($g/dm^2/h$)	Wind speed (km/h)	Failure*
OS2003(2)	UCAR EG ADF	-9.9 ± 0.03	4.44	10 to 15	6 min 44 s
OS2005(3)	UCAR EG ADF	-5.8 ± 0.15	4.94	0 to 1	16 min 00 s
OS2005(3)	UCAR EG ADF	-5.8 ± 0.16	4.94	0 to 1	16 min 00 s
OS2007(1) (no spreader)	UCAR EG ADF	-6.9 ± 0.03	3.76	10 to 15	12 min 55 s
OS2007(1)	UCAR EG ADF	-6.9 ± 0.03	3.76	10 to 15	12 min 34 s
OS2007(6) (no spreader)	UCAR EG ADF	-7.2 ± 0.02	4.13	0 to 5	12 min 08 s
OS2007(6)	UCAR EG ADF	-7.1 ± 0.03	4.16	0 to 5	11 min 00 s
OS2009(1)	UCAR EG ADF	-10.6 ± 0.28	3.63	0 to 3	13 min 52 s
OS2009(1)	UCAR EG ADF	-10.6 ± 0.28	3.63	0 to 3	13 min 45 s
OS2011(4)	UCAR EG ADF	-10.7 ± 0.06	2.27	13 to 14	12 min 08 s
OS2011(4)	UCAR EG ADF	-10.7 ± 0.06	5.36	13 to 14	9 min 19 s
OS2012(3)	UCAR EG ADF	-14.7 ± 0.03	2.61	20 to 30	14 min 00 s
OS2012(3)	UCAR EG ADF	-14.7 ± 0.03	2.61	20 to 30	12 min 43 s
OS2013(1)	UCAR EG ADF	-14.7 ± 0.21	10.24	20 to 30	7 min 25 s
OS2013(1)	UCAR EG ADF	-15.1 ± 0.09	9.20	20 to 30	10 min 25 s
OS2016(1)	UCAR EG ADF	-9.3	6.00	± 16	12 min 00 s
OS2016(1)	UCAR EG ADF	-9.3	3.37	± 16	27 min 32 s
OS2016(5)	UCAR EG ADF	-8.7	4.86	4	8 min 10 s
OS2016(5)	UCAR EG ADF	-8.7	7.40	4	6 min 12 s
OS2018(2) (with thermos)	UCAR EG ADF	-11.0 ± 0.18	4.40	± 10	8 min 56 s
OS2018(2)	UCAR EG ADF	-10.9 ± 0.11	4.69	± 10	10 min 10 s
OS2018(7) (with thermos)	UCAR EG ADF	-10.8 ± 0.04	6.92	16 to 22	6 min 19 s
OS2018(7)	UCAR EG ADF	-10.8 ± 0.05	6.92	16 to 22	6 min 15 s
OS2019(2)	UCAR EG ADF	-10.8 ± 0.08	8.00	15 to 25	7 min 42 s
OS2019(2)	UCAR EG ADF	-10.9 ± 0.11	8.00	15 to 25	8 min 13 s
OS2019(7)	UCAR EG ADF	-11.8 ± 0.04	14.00	20 to 25	5 min 20 s
OS2019(7)	UCAR EG ADF	-11.9 ± 0.04	12.72	20 to 25	4 min 55 s
OS2019(12)	UCAR EG ADF	-11.9 ± 0.03	27.20	20 to 36	2 min 50 s
OS2019(17)	UCAR EG ADF	-11.7 ± 0.02	17.76	20 to 30	4 min 18 s
OS2001(1)	UCAR ADF XL54	-3.2 ± 0.14	6.42	5 to 9	16 min 10 s
OS2001(1)	UCAR ADF XL54	-3.3 ± 0.06	6.13	5 to 9	13 min 55 s
OS2001(5)	UCAR ADF XL54	-3.7 ± 0.04	3.39	7	21 min 25 s
OS2001(5)	UCAR ADF XL54	-3.7 ± 0.04	1.95	7	25 min 51 s
OS2002(1)	UCAR ADF XL54	-3.1 ± 0.14	4.05	5	15 min 00 s
OS2002(1)	UCAR ADF XL54	-3.1 ± 0.15	4.00	5	17 min 13 s
OS2004(2)	UCAR ADF XL54	-13.0	0.80	± 7	28 min 04 s
OS2006(1)	UCAR ADF XL54	-8.9 ± 0.09	5.63	9 to 15	14 min 28 s
OS2006(1)	UCAR ADF XL54	-8.9 ± 0.08	5.63	9 to 15	12 min 45 s
OS2007(5) (no spreader)	UCAR ADF XL54	-7.1 ± 0.02	4.12	0 to 5	17 min 04 s
OS2007(5)	UCAR ADF XL54	-7.1 ± 0.01	4.45	0 to 5	13 min 00 s
OS2008(3)	UCAR ADF XL54	-4.4 ± 0.04	1.80	0 to 5	27 min 10 s
OS2008(3)	UCAR ADF XL54	-4.4 ± 0.04	1.80	0 to 5	26 min 22 s
OS2011(3)	UCAR ADF XL54	-10.8 ± 0.06	8.06	20	10 min 00 s
OS2011(3)	UCAR ADF XL54	-10.8 ± 0.08	6.20	20	15 min 12 s
OS2015(1)	UCAR ADF XL54	-7.8 ± 0.02	22.56	0 to 8.6	4 min 42 s

Table 4.9: Log of Type I Protocol Tests (AMIL) – continued

# Test	Fluid	T_{air} (°C)	Intensity (g/dm²/h)	Wind speed (km/h)	Failure*
OS2015(1)	UCAR ADF XL54	-7.8 ± 0.01	22.56	0 to 8.6	4 min 57 s
OS2015(4)	UCAR ADF XL54	-7.4 ± 0.02	11.48	0 to 8.6	8 min 19 s
OS2015(4)	UCAR ADF XL54	-7.4 ± 0.02	11.48	0 to 8.6	7 min 47 s
OS2015(7)	UCAR ADF XL54	-7.6 ± 0.08	9.04	5 to 10	7 min 30 s
OS2015(7)	UCAR ADF XL54	-7.6 ± 0.07	9.04	5 to 10	8 min 43 s
OS2015(10)	UCAR ADF XL54	-8.0 ± 0.07	8.08	10 to 15	8 min 30 s
OS2015(10)	UCAR ADF XL54	-8.0 ± 0.06	8.08	10 to 15	7 min 57 s
OS2015(13)	UCAR ADF XL54	-9.2 ± 0.22	9.32	10 to 15	8 min 25 s
OS2015(13)	UCAR ADF XL54	-9.3 ± 0.14	9.32	10 to 15	8 min 19 s
OS2016(4)	UCAR ADF XL54	-8.8	3.20	± 16	14 min 50 s
OS2016(4)	UCAR ADF XL54	-8.8	3.20	± 16	14 min 30 s
OS2018(5) (with thermos)	UCAR ADF XL54	-10.4 ± 0.02	11.96	16 to 22	7 min 35 s
OS2018(5)	UCAR ADF XL54	-10.4 ± 0.02	11.96	16 to 22	6 min 30 s
OS2018(10) (with thermos)	UCAR ADF XL54	-11.1 ± 0.03	9.65	24 to 40	10 min 19 s
OS2018(10)	UCAR ADF XL54	-11.1 ± 0.02	11.04	24 to 40	8 min 24 s
OS2019(5)	UCAR ADF XL54	-11.6 ± 0.04	10.64	20 to 22	9 min 15 s
OS2019(5)	UCAR ADF XL54	-11.6 ± 0.03	10.64	20 to 22	9 min 01 s
OS2019(10)	UCAR ADF XL54	-11.9 ± 0.02	10.56	20 to 30	7 min 54 s
OS2019(10)	UCAR ADF XL54	-11.9 ± 0.02	10.56	20 to 30	7 min 14 s
OS2019(15)	UCAR ADF XL54	-11.8 ± 0.02	16.60	20 to 30	9 min 07 s
OS2019(15)	UCAR ADF XL54	-11.9 ± 0.03	10.04	20 to 30	6 min 27 s
OS2001(3)	UCAR PG ADF	-3.5 ± 0.03	3.72	5 to 9	16 min 05 s
OS2001(3)	UCAR PG ADF	-3.5 ± 0.03	3.71	5 to 9	14 min 37 s
OS2002(3)	UCAR PG ADF	-3.6 ± 0.08	2.46	5	19 min 46 s
OS2002(3)	UCAR PG ADF	-3.7 ± 0.05	2.44	5	16 min 40 s
OS2003(3)	UCAR PG ADF	-10.0 ± 0.04	3.07	10 to 15	10 min 40 s
OS2003(3)	UCAR PG ADF	-10.0 ± 0.05	3.07	10 to 15	10 min 52 s
OS2007(2) (no spreader)	UCAR PG ADF	-6.8 ± 0.02	4.67	10 to 15	12 min 45 s
OS2007(2)	UCAR PG ADF	-6.9 ± 0.02	4.67	10 to 15	10 min 18 s
OS2007(7) (no spreader)	UCAR PG ADF	-7.4 ± 0.03	1.89	0 to 5	22 min 28 s
OS2007(7)	UCAR PG ADF	-7.3 ± 0.03	1.98	0 to 5	15 min 20 s
OS2009(2)	UCAR PG ADF	-9.7 ± 0.52	0.86	0 to 3	17 min 34 s
OS2009(2)	UCAR PG ADF	-9.7 ± 0.49	1.00	0 to 3	19 min 35 s
OS2011(5)	UCAR PG ADF	-10.7 ± 0.06	1.47	13 to 14	10 min 42 s
OS2012(2)	UCAR PG ADF	-14.6 ± 0.08	5.12	20 to 30	6 min 40 s
OS2012(2)	UCAR PG ADF	-14.6 ± 0.06	5.08	20 to 30	6 min 43 s
OS2015(3)	UCAR PG ADF	-7.5 ± 0.02	16.20	0 to 8.6	6 min 23 s
OS2015(3)	UCAR PG ADF	-7.5 ± 0.02	13.56	0 to 8.6	5 min 56 s
OS2015(6)	UCAR PG ADF	-7.4 ± 0.07	8.08	5 to 10	6 min 34 s
OS2015(6)	UCAR PG ADF	-7.4 ± 0.05	8.08	5 to 10	7 min 45 s
OS2015(9)	UCAR PG ADF	-7.6 ± 0.13	10.64	10 to 15	5 min 57 s
OS2015(9)	UCAR PG ADF	-7.6 ± 0.14	10.64	10 to 15	6 min 10 s
OS2015(12)	UCAR PG ADF	-8.8 ± 0.05	5.80	10 to 15	7 min 20 s
OS2015(12)	UCAR PG ADF	-8.8 ± 0.05	5.80	10 to 15	7 min 28 s
OS2015(15)	UCAR PG ADF	-10.2 ± 0.03	2.53	15 to 20	12 min 52 s

Table 4.9: Log of Type I Protocol Tests (AMIL) – continued

# Test	Fluid	T_{air} (°C)	Intensity (g/dm²/h)	Wind speed (km/h)	Failure*
OS2015(15)	UCAR PG ADF	-10.2 ± 0.04	2.40	15 to 20	14 min 30 s
OS2016(2)	UCAR PG ADF	-9.4	0.86	± 16	20 min 40 s
OS2016(2)	UCAR PG ADF	-9.4	1.20	± 16	20 min 45 s
OS2016(6)	UCAR PG ADF	-8.0	4.15	4	27 min 10 s
OS2018(3) (with thermos)	UCAR PG ADF	-10.7 ± 0.20	4.92	10 to 15	7 min 46 s
OS2018(3)	UCAR PG ADF	-10.9 ± 0.25	4.92	10 to 15	8 min 55 s
OS2018(8) (with thermos)	UCAR PG ADF	-11.1 ± 0.05	3.28	16 to 22	12 min 10 s
OS2018(8)	UCAR PG ADF	-11.1 ± 0.04	3.28	16 to 22	10 min 49 s
OS2019(3)	UCAR PG ADF	-11.2 ± 0.04	9.64	±15	5 min 50 s
OS2019(3)	UCAR PG ADF	-11.2 ± 0.04	9.64	±15	5 min 39 s
OS2019(8)	UCAR PG ADF	-12.0 ± 0.01	13.28	20 to 25	4 min 02 s
OS2019(13)	UCAR PG ADF	-11.9 ± 0.01	23.04	20 to 30	3 min 10 s
OS2019(13)	UCAR PG ADF	-11.9 ± 0.01	23.04	20 to 30	2 min 52 s
OS2019(18)	UCAR PG ADF	-11.6 ± 0.02	4.52	20 to 30	6 min 33 s
OS2019(18)	UCAR PG ADF	-11.6 ± 0.02	4.52	20 to 30	5 min 25 s
OS2003(1)	Octagon Octaflo EF Premix	-9.8 ± 0.03	5.65	10 to 15	11 min 40 s
OS2003(1)	Octagon Octaflo EF Premix	-9.8 ± 0.03	5.65	10 to 15	10 min 24 s
OS2004(1)	Octagon Octaflo EF Premix	-10.5	1.84	± 2	14 min 07 s
OS2004(1)	Octagon Octaflo EF Premix	-10.5	1.97	± 2	14 min 32 s
OS2006(2)	Octagon Octaflo EF Premix	-8.4 ± 0.18	2.11	9 to 15	29 min 40 s
OS2006(2)	Octagon Octaflo EF Premix	-8.4 ± 0.14	2.40	9 to 15	23 min 25 s
OS2007(4) (no spreader)	Octagon Octaflo EF Premix	-7.0 ± 0.04	4.29	10 to 15	14 min 07 s
OS2007(4)	Octagon Octaflo EF Premix	-7.0 ± 0.05	4.64	10 to 15	12 min 50 s
OS2008(1)	Octagon Octaflo EF Premix	-4.4 ± 0.01	18.04	0 to 5	7 min 45 s
OS2008(1)	Octagon Octaflo EF Premix	-4.5 ± 0.02	18.04	0 to 5	6 min 42 s
OS2010(1)	Octagon Octaflo EF Premix	-10.8 ± 0.35	2.21	10	13 min 50 s
OS2010(1)	Octagon Octaflo EF Premix	-11.0 ± 0.32	1.74	10	16 min 31 s
OS2011(2)	Octagon Octaflo EF Premix	-10.7 ± 0.08	2.23	14	28 min 37 s
OS2011(2)	Octagon Octaflo EF Premix	-10.8 ± 0.05	2.01	14	26 min 00 s
OS2012(1)	Octagon Octaflo EF Premix	-14.4 ± 0.07	5.40	20 to 30	8 min 35 s
OS2012(1)	Octagon Octaflo EF Premix	-14.4 ± 0.06	5.40	20 to 30	8 min 14 s
OS2012(4)	Octagon Octaflo EF Premix	-14.6 ± 0.03	2.43	20 to 30	10 min 02 s
OS2012(4)	Octagon Octaflo EF Premix	-14.6 ± 0.03	2.24	20 to 30	6 min 55 s
OS2018(1) (with thermos)	Octagon Octaflo EF Premix	-10.4 ± 0.1	8.04	± 10	9 min 14 s
OS2018(1)	Octagon Octaflo EF Premix	-10.5 ± 0.07	8.04	± 10	9 min 39 s
OS2018(6) (with thermos)	Octagon Octaflo EF Premix	-10.6 ± 0.02	9.72	16 to 22	7 min 00 s
OS2018(6)	Octagon Octaflo EF Premix	-10.6 ± 0.02	9.72	16 to 22	6 min 00 s
OS2019(1)	Octagon Octaflo EF Premix	-10.6 ± 0.04	9.88	16.5 to 23	9 min 35 s
OS2019(1)	Octagon Octaflo EF Premix	-10.6 ± 0.05	9.88	16.5 to 23	8 min 52 s
OS2019(6)	Octagon Octaflo EF Premix	-11.7 ± 0.05	6.36	20 to 22	8 min 45 s
OS2019(6)	Octagon Octaflo EF Premix	-11.7 ± 0.04	6.36	20 to 22	7 min 36 s
OS2019(11)	Octagon Octaflo EF Premix	-11.9 ± 0.02	9.25	28 to 36	10 min 10 s
OS2019(11)	Octagon Octaflo EF Premix	-11.9 ± 0.02	11.04	28 to 36	8 min 37 s
OS2019(16)	Octagon Octaflo EF Premix	-11.8 ± 0.02	19.44	20 to 30	5 min 03 s
OS2019(16)	Octagon Octaflo EF Premix	-11.7 ± 0.02	19.44	20 to 30	4 min 18 s

* - 30% snow

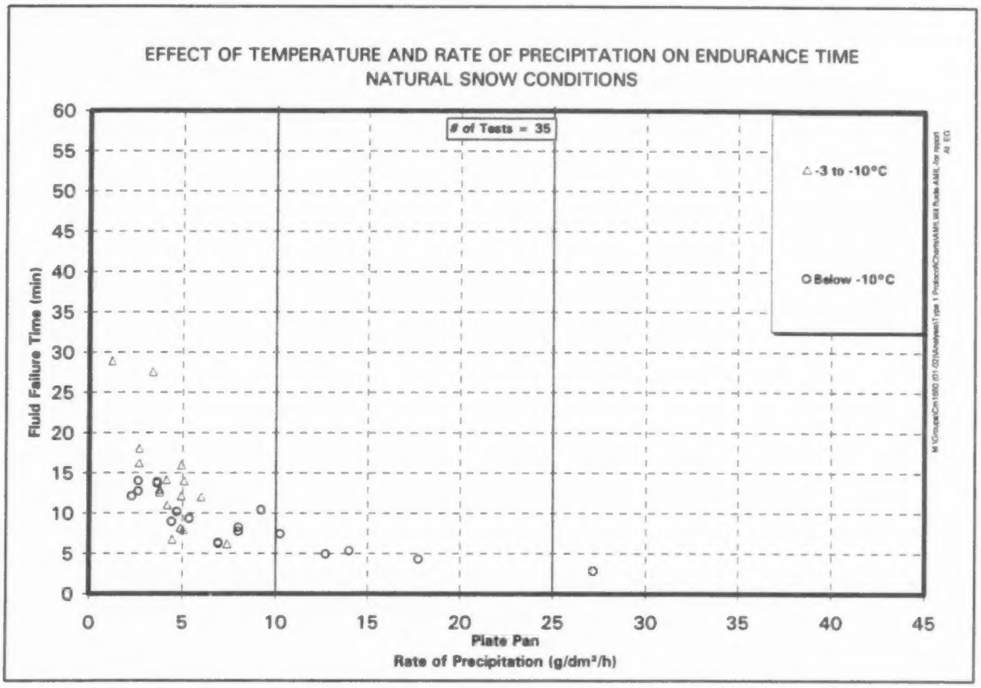

Figure 4.16: UCAR EG ADF (10° Buffer) on Boxes – AMIL Data

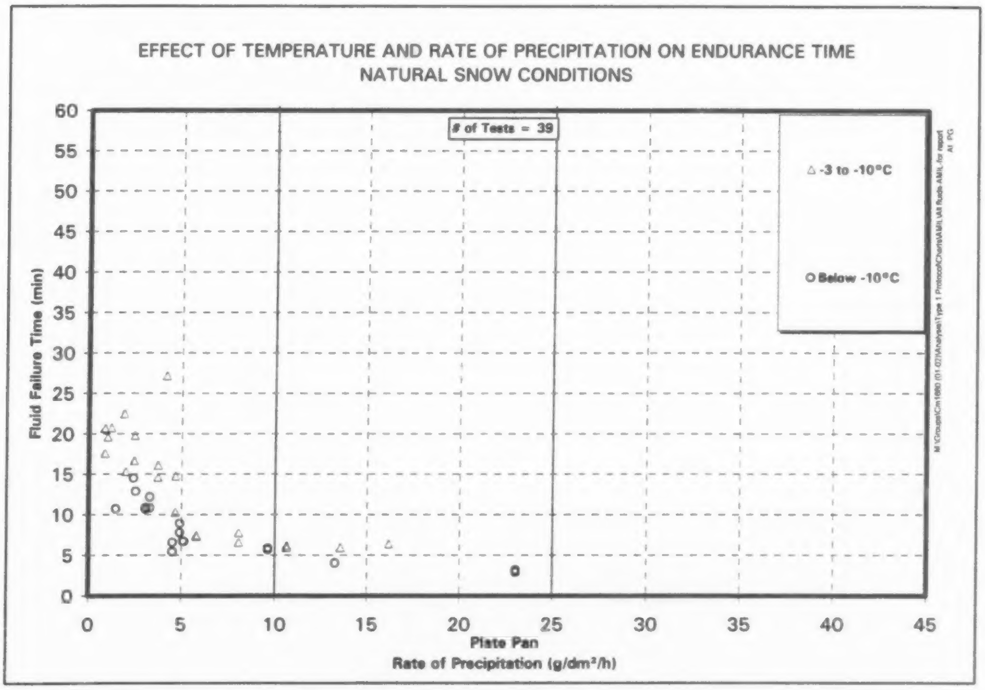

Figure 4.17: UCAR PG ADF (10° Buffer) on Boxes – AMIL Data

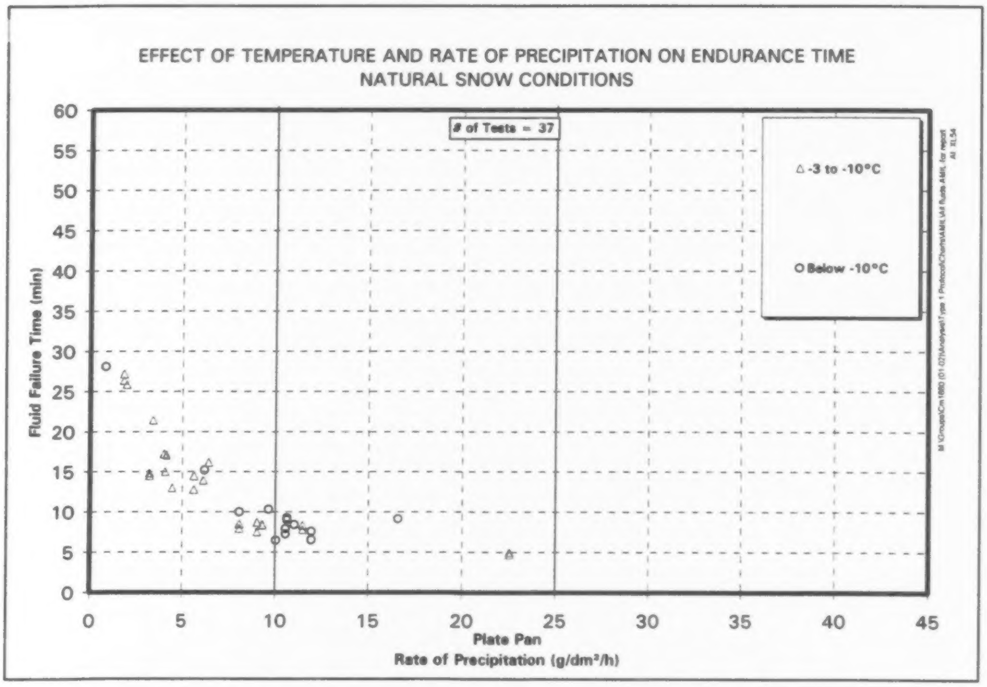

Figure 4.18: UCAR ADF XL54 on Boxes – AMIL Data

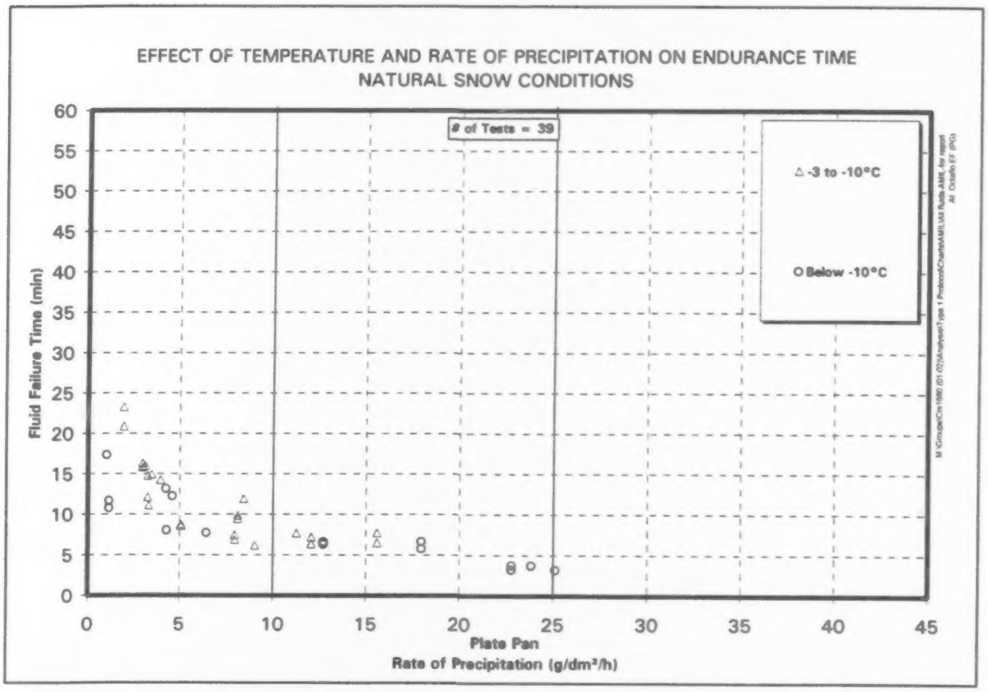

Figure 4.19: OCTAFLO EF PG (10° Buffer) on Boxes – AMIL Data

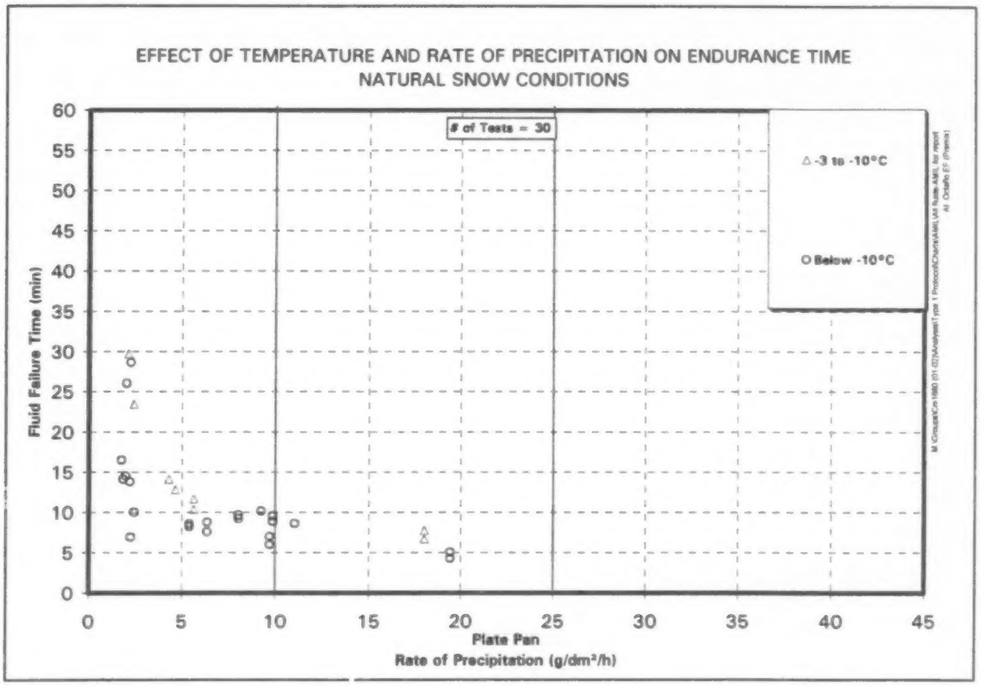

Figure 4.20: OCTAFLO EF PG (Premix) on Boxes – AMIL Data

4.4.7 Combined Results (APS and AMIL)

To allow a global analysis, the results obtained by APS were combined with AMIL's data set. The new Type I protocol addresses only 10° buffer fluids and even though both APS and AMIL have done tests with standard mix concentration fluids, for the purpose of this report they were not included in the analysis. The tests conducted on plates using a 10° buffer fluid were used as a baseline for comparison and they were disregarded for the combined analysis. The final data set comprises exclusively 10° buffer fluid box tests completed by APS and AMIL using ethylene- and propylene-based Type I fluids.

The summary of combined results from APS and AMIL analysed in this study is shown in Table 4.10.

Table 4.10: Endurance Time Tests Completed by APS and AMIL

Fluid Name	Number of Tests
UCAR EG ADF	77
UCAR PG ADF	77
Octagon Octaflo EF	39
TOTAL	193

Figure 4.21 shows a temperature breakdown of the combined tests completed by APS and AMIL during the winter of 2001-02. As observed, APS conducted tests primarily in the -9 to 0°C temperature range and slightly above, while AMIL obtained data predominantly at lower ambient temperatures.

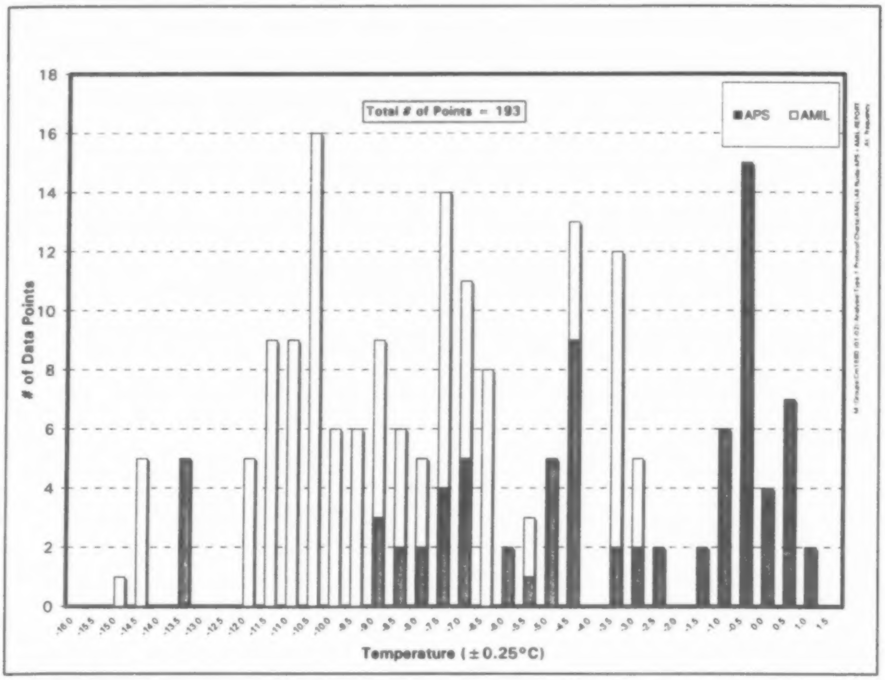

Figure 4.21: Temperature Distribution – Natural Snow 2001-02

Figure 4.22 to Figure 25 illustrate the combined results from APS and AMIL at the following temperature ranges: above 0°, 0 to -3°C, -3 to -10°C, and below -10°C. Each chart illustrates one of these temperature breakdowns, and shows the data points collected by APS and AMIL within the specific temperature band. On the first two charts (Figure 4.22 and Figure 23), the data comes from APS solely, because AMIL did not conduct endurance time tests above an outside air temperature of -3°C.

4.5 Analysis and Observations

Data presented in Subsection 4.4 is analyzed and discussed in the remainder of this section. The final result of this section is the snow columns of the Type I HOT table for the combined data set from AMIL and APS. These columns are part of the final Type I HOT table to be used in the 2002-03 winter.

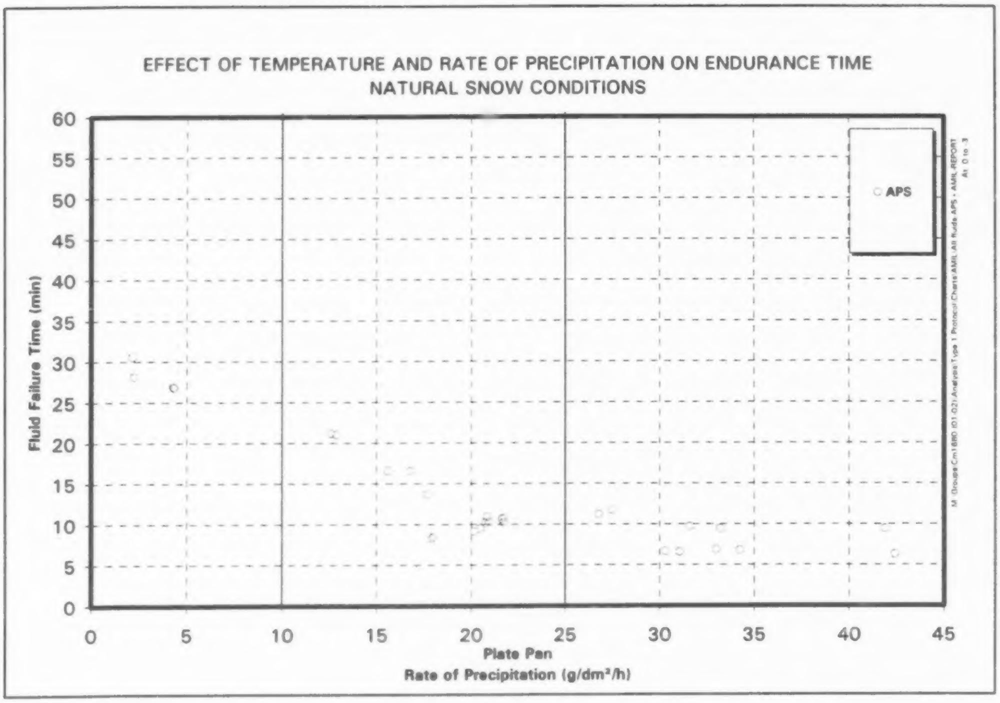

Figure 4.22: Type I Fluids (10° Buffer) at Above 0°C

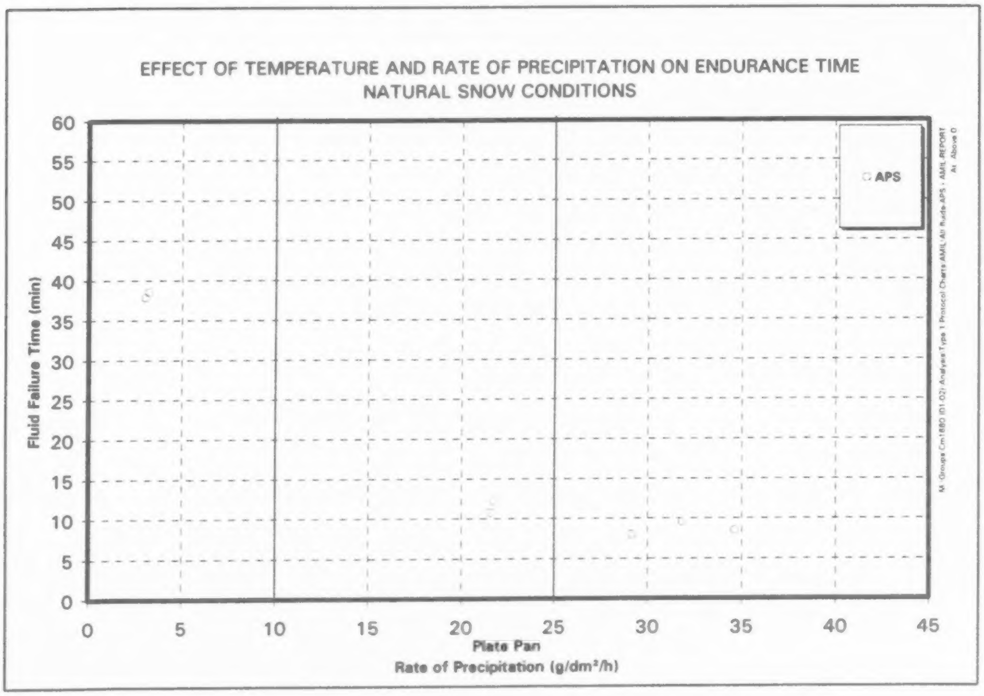

Figure 4.23: Type I Fluids (10° Buffer) at 0 to -3°C

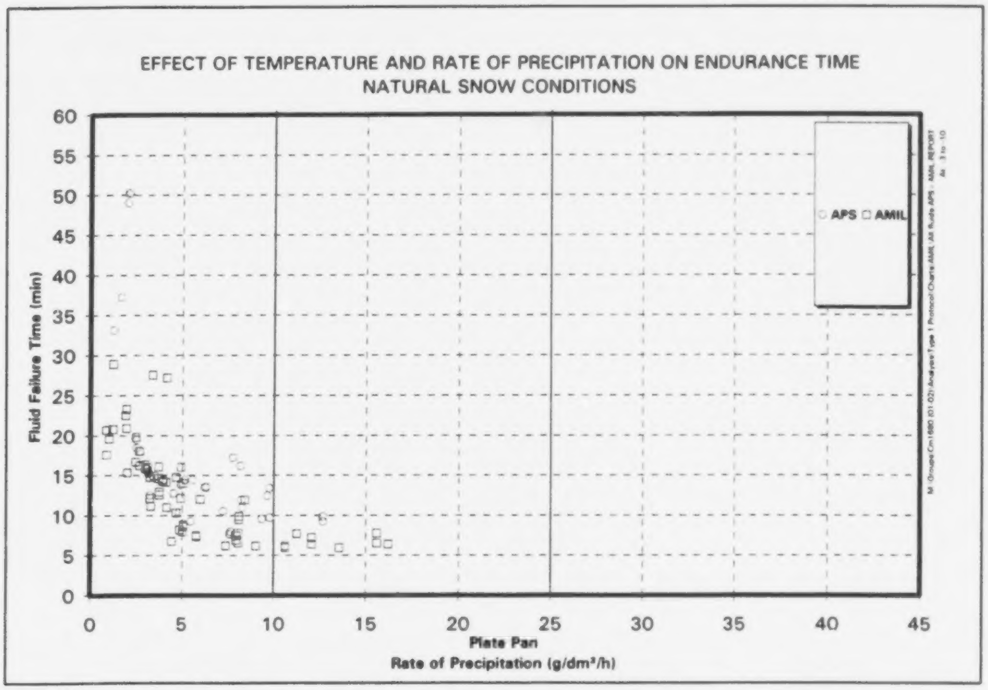

Figure 4.24: Type I Fluids (10° Buffer) at -3 to -10°C

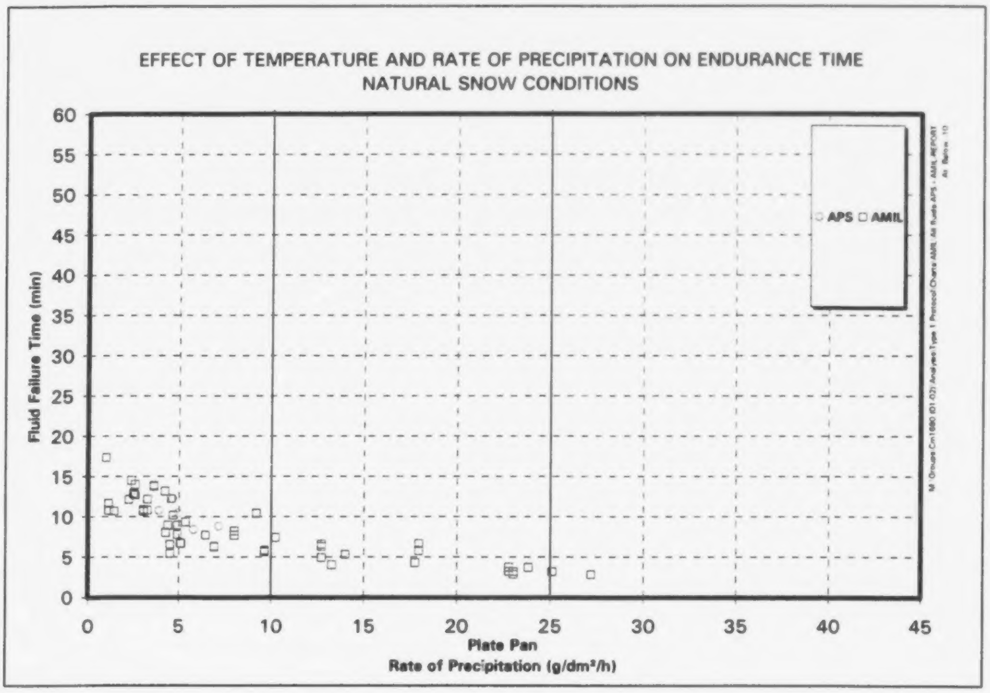

Figure 4.25: Type I Fluids (10° Buffer) at Below -10°C

4.5.1 Comparison of 10°C Buffer Fluid vs. Premix Concentration

The values reported in the current generic Type I HOT guideline are based on fluid endurance tests using fluid mixed to a concentration such that their freeze point is 10°C below OAT. In actual practice, many operators do not mix the fluid according to OAT but simply apply full operating strength (referred to as 50/50 mix) fluid. Measurements of rates of dilution have indicated that the higher initial concentration is not useful during precipitation with higher rates such as 25 g/dm²/h, because dilution occurs very rapidly regardless of increased fluid strength. However, at lower precipitation rates and at mild temperatures, a fluid with a 50/50 mix takes longer to dilute than a fluid mixed to a freeze point 10°C below OAT and, consequently will generate a longer endurance time.

A HOT table having cells that recognize variability in fluid strength (50/50 and 10°C FFP buffer) was considered. For this reason, the APS data set obtained during the winter of 2001-02 was analysed to determine the differences between the two fluid concentrations. The results are presented in Figure 4.26 and Figure 4.27 for ethylene-based fluids and propylene-based fluids, respectively.

4.5.1.1 Premix vs. 10°C buffer – APS

To facilitate this type of comparison, each pair of 10°C buffer and standard mix fluid was tested at the same time, so both test surfaces were subjected to the same outside air temperature, wind speed, and precipitation rate. APS conducted 34 tests using ethylene-based fluids (UCAR EG ADF and UCAR ADF XL54) and 11 tests using propylene-based fluids (UCAR PG ADF and UCAR PG ADF FFP-34°C). The effect of fluid type seemed insignificant since the endurance time ratio between the standard mix and 10°C buffer fluids was 1.1 in both cases. In other words, the standard mix fluid had an average holdover time of about 10 percent longer than the 10° buffer fluid.

4.5.1.2 Premix vs. 10°C buffer - AMIL

AMIL tested two premix concentration fluids UCAR ADF XL45 and Octagon Octaflo EF PG (Premix). The endurance time tests on 10°C buffer fluids and standard mix fluids were not necessarily conducted simultaneously. For the two fluids tested, the results based on regression analysis show an increase in the endurance times of 25 percent and 20 percent, respectively, with the standard mix concentration fluid.

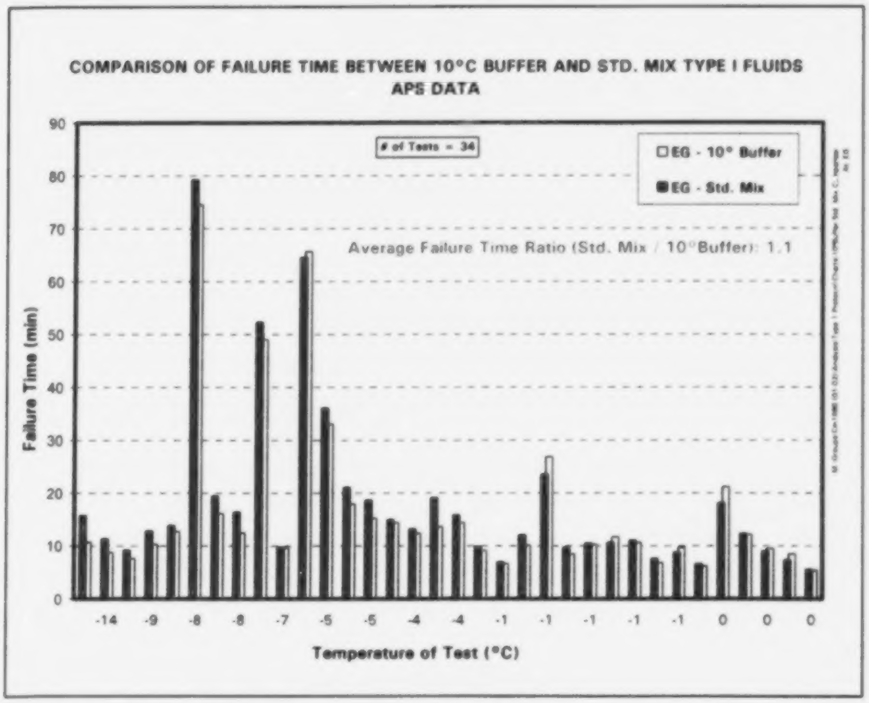

Figure 4.26: 10°C Buffer vs. Std. Mix Comparison – Type I EG Fluids

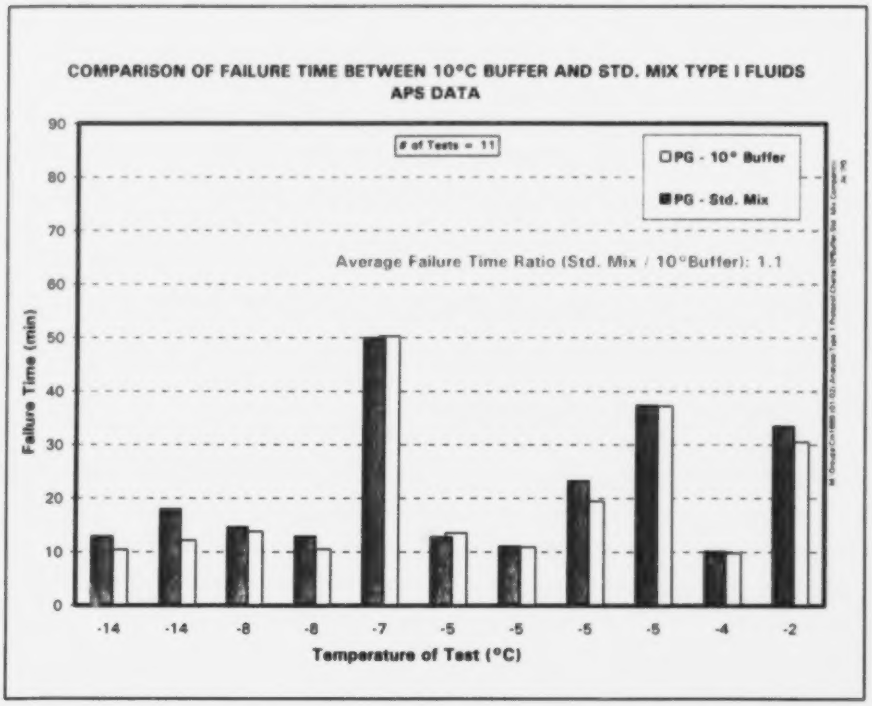

Figure 4.27: 10°C Buffer vs. Std. Mix Comparison – Type I PG Fluids

The difference in the endurance times between 50/50 fluids and the 10°C buffer fluids, for the benefit of 50/50 fluids, is generated by the different glycol concentration of the two fluids. 50/50 fluids contain more glycol in the aqueous solution than 10°C buffer fluids.

4.5.1.3 Heat transfer mechanisms

To understand the phenomena that take place on the test surface after pouring the fluid, a few observations are worth mentioning regarding the application of water versus fluid mix (equal quantities and temperatures):

a) Water has a higher specific heat and thermal conductivity resulting in higher peak temperatures after application. This tends to cause more enrichment;

b) Because of better conductivity, a water-treated surface will cool faster. At that stage, more heat is transferred to the plate by convection with water as compared to the fluid mix; and

c) When glycol and water are mixed to 50/50, for example, the thermal characteristic values of the mix will be (roughly) the average.

4.5.1.4 Premix vs. 10°C buffer – results and considerations

It is believed that the difference in results obtained by APS and AMIL is related to the temperature at which the tests were conducted. On average, AMIL conducted tests at colder temperatures.

Based on these results, a Type I HOT table having cells that recognize variability in fluid strength (50/50 and 10°C FFP buffer) for Type I fluids is not recommended at this time.

It would be useful to understand the impact of a premix at different temperatures, wind speeds, and weather conditions for the HOT table, as shown in Table 4.11.

A theoretical model, based on the UCAR PG ADF dilution table, shows that at low temperatures and precipitation rates there is some benefit to endurance time gained by using the premix fluid instead of the 10°C buffer fluid. As the precipitation rate increases and the outside air temperature decreases these differences tend to disappear since the glycol concentrations of the two fluids grow closer and the quantity of water equivalent precipitation that has fallen onto the surfaces becomes more significant.

Table 4.11: Guideline for Selecting the Most Efficient Fluid Dilution

OAT (°C)	Very Light Snow			Light Snow			Moderate Snow			Heavy Snow		
	L	M	H	L	M	H	L	M	H	L	M	H
Above -3	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix
-3 to -10	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix
Below -10	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix	10°B or Premix

B 10°C buffer dilution **NOTES**
L Low wind speed
M Moderate wind speed
H High wind speed
or standard mix dilution

At higher precipitation rates the fluid reaches its freeze point a few minutes before failure. Surface protection is being provided mostly by heat in these cases. In the event of high wind speeds, this heat protection could be taken away, significantly diminishing the endurance time of the fluid. When this is the case, the use of higher glycol concentration fluid (premix) could provide additional endurance time.

The cost effectiveness of using 50/50 mix versus dilute fluid is very low. In some conditions, no additional endurance time is given. In heavy precipitation, 50/50 fluid dilutes very quickly and provides limited protection.

4.5.2 Methodology Used to Determine Holdover Times

Each cell in a HOT table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. Each cell contains a lower and upper time limit (except for frost) for a maximum of 34 time values.

Holdover time values in each cell are determined by plotting *failure time* versus *rate of precipitation* and recording the failure time at the pre-selected rate limits. In previous years, several protocols were employed in determining holdover times. A multi-variable regression approach was devised in 1996-97 (see TC report TP 13131E *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1996-97 Winter* (7)) and has been used to evaluate anti-icing fluid endurance times for the past six test seasons. Endurance times were then converted to holdover times by the SAE G-12 Holdover Time Subcommittee.

The data points were used to fit an equation of the form:

$t = cR^a(2-T)^b$, where

t = Time (minutes);
T = Temperature (°C);
R = Rate of precipitation (g/dm^2/h); and
a,b,c = Coefficients determined from the regression.

The best-fit curves were generated from the above equation using the coefficients determined from the regression and superimposed onto the data plot. The holdover time range was determined from the intersection of the best-fit curves with the precipitation rate limits. Best-fit curves were plotted in each cell of the snow column using the most restrictive (lowest) temperature for that cell. The upper and lower holdover time values were determined from the points at which the best-fit curve intersected the lower and upper precipitation limits, respectively.

The curves produced using the regression analysis method attempt to determine the worst possible holdover time value in each cell of the HOT table.

4.5.3 Influence of Fluid Brand on Endurance Time

The snow data points obtained by APS during the winter of 2001-02 using 10° Buffer Type I fluids on boxes were analysed according to the method described in Subsection 4.5.2. For each of the fluids (UCAR EG ADF and UCAR PG ADF), four curves were generated from the regression and corresponded to the lowest temperature in each cell of the HOT table. The results are presented in Figure 4.28 and Figure 4.29.

In order to determine whether the type of fluid used has an influence on the endurance time, the test results from these two fluids for similar conditions were compared. Using the output from the regression, an endurance time was calculated for each fluid using the average rate of 14 g/dm^2/h and the average air temperature of -4°C. UCAR EG ADF produced an endurance time of 9 minutes while UCAR PG ADF had an ET of 9.5 minutes. Thus, on average, the propylene-based fluid had an endurance time 5 percent greater than the ethylene-based fluid.

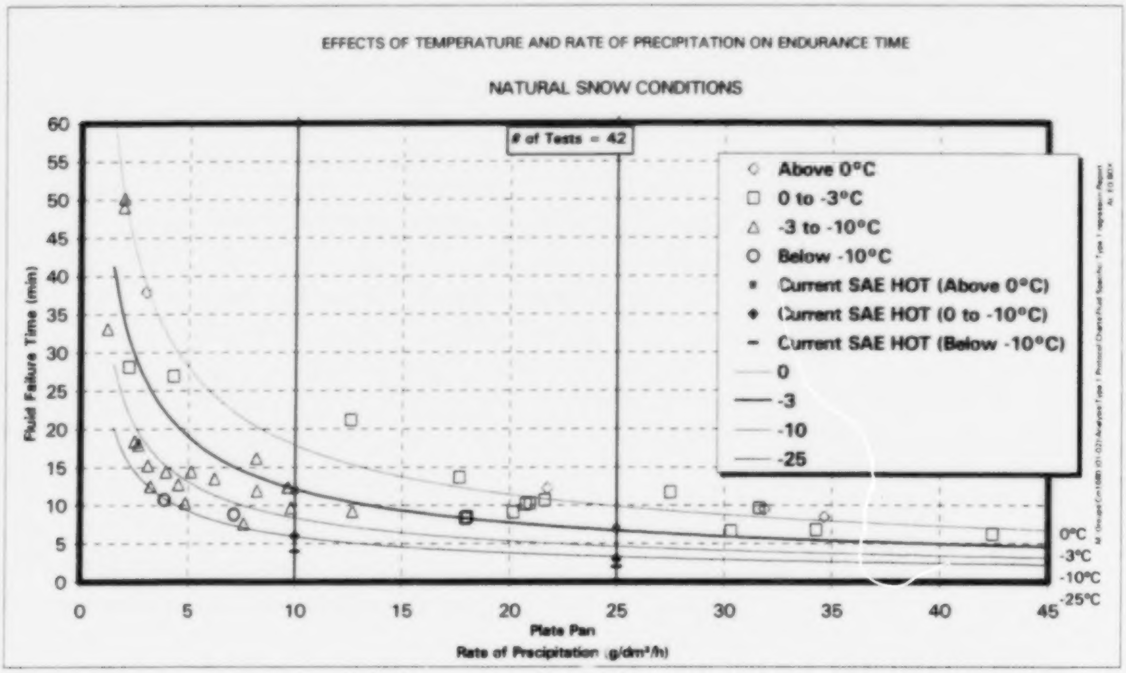

Figure 4.28: Regression Curves – UCAR EG ADF (10° Buffer) – APS Data

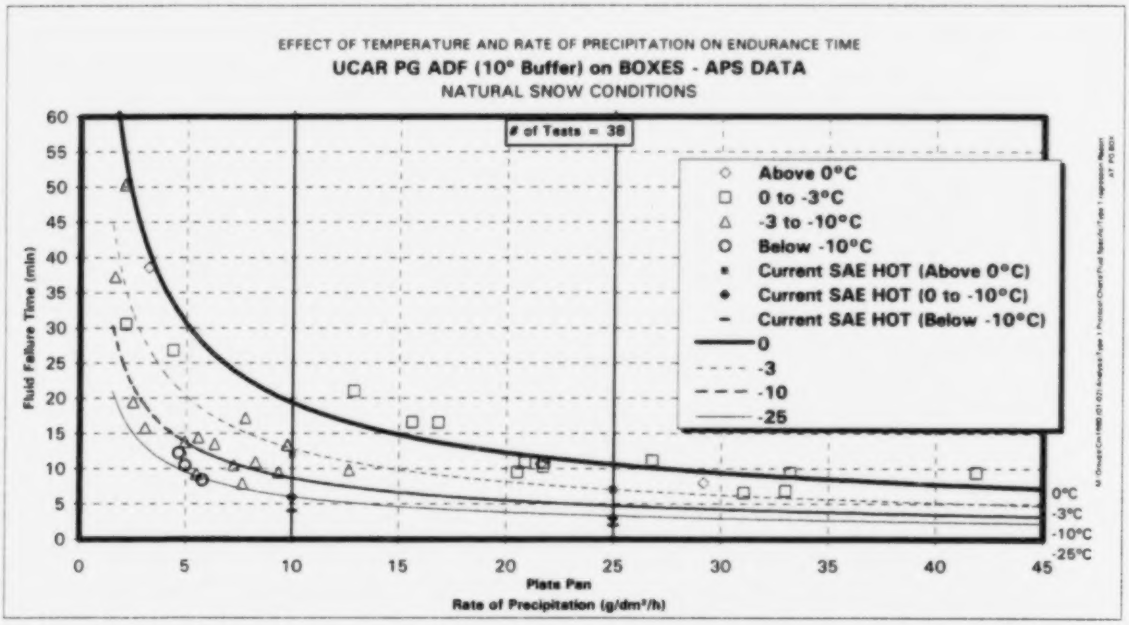

Figure 4.29: Regression Curves – UCAR PG ADF (10° Buffer) – APS Data

AMIL conducted 113 tests in natural snow using 10° Buffer Type I fluids. AMIL tested one ethylene-based fluid and two propylene-based fluids, as described in Subsection 4.3.4.

Using the same methodology as for the APS data set, the regression curves were produced for each of the three fluids. These are illustrated in Figure 4.30 to Figure 4.32.

For an average precipitation rate of 7 g/dm²/h and an average air temperature of -9°C, an endurance time was calculated for each fluid type. The two propylene-based fluids were grouped and analysed as one data set. UCAR EG ADF produced an endurance time of 8.4 minutes and the propylene-based fluids had an ET of 7.9 minutes. Thus, on average, the ethylene-based fluid had an endurance time 6 percent greater than the propylene-based fluid.

Based on these results obtained by APS and AMIL, fluid type does not seem to have a great impact on the endurance time.

4.5.4 APS Endurance Time Results

To produce numbers for each cell of the snow column, the test results from ethylene- and propylene-based fluids were combined and analysed together.

APS had done 80 10° Buffer Type I tests in natural snow during the winter of 2001-02. The results are shown in Figure 4.33.

Based on the values generated by the regression equation from the combined data set and rounding these numbers down, the results from APS testing were obtained. These are summarized in Table 4.12. The numbers are presented according to the new Type I HOT table format. TC has selected a lower limit of 3 g/dm²/h to be used for the *light snow* column; however the FAA selected a lower limit of 5 g/dm²/h. Since a common lower precipitation limit for light snow is yet to be agreed upon by TC and the FAA, the cells in the *light snow* column contain only numbers from Transport Canada.

4.5.5 AMIL Endurance Time Results

AMIL conducted 113 tests in natural snow using 10° Buffer Type I fluids; one ethylene-based fluid and two propylene-based fluids The test results for the three fluids were combined into one data set. The values generated by the regression equation from this data set, for each temperature, are presented in Figure 4.34.

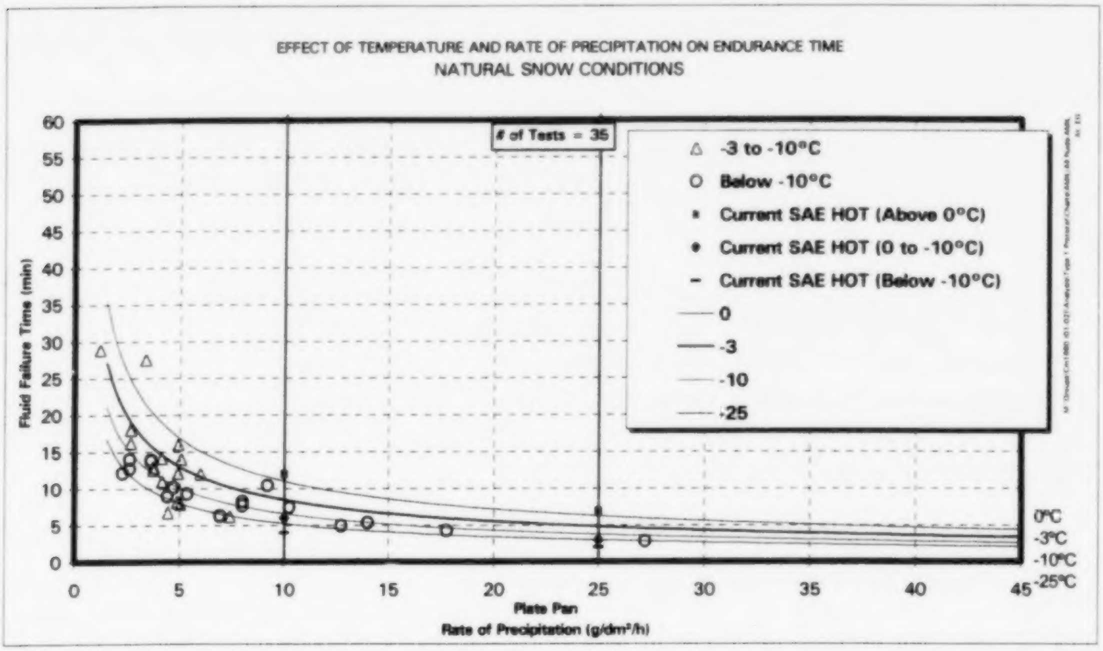

Figure 4.30: Regression Curves – UCAR EG ADF (10° Buffer) – AMIL Data

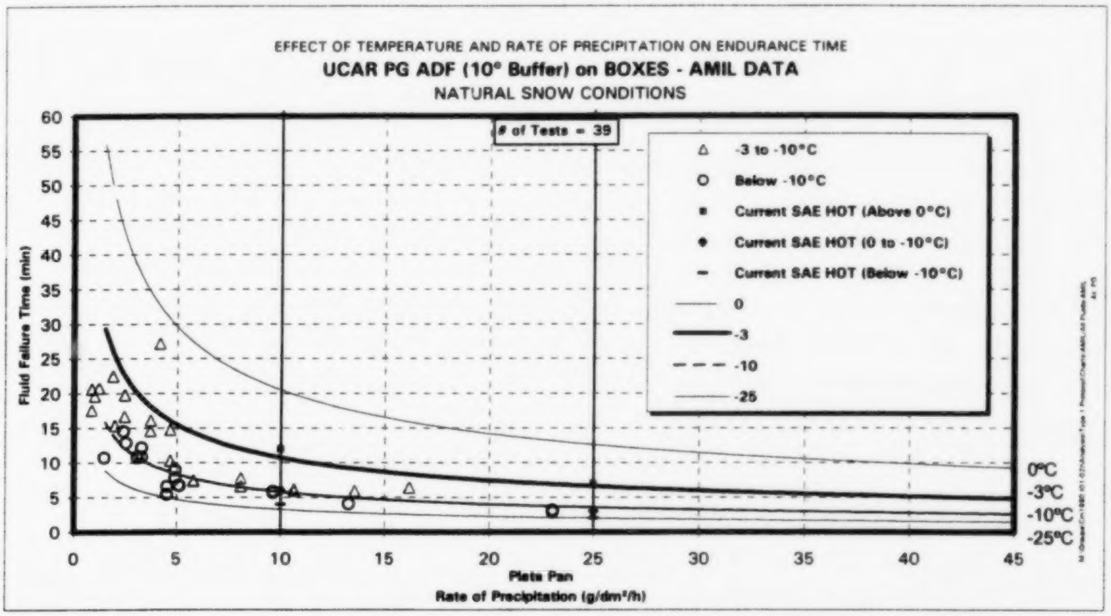

Figure 4.31: Regression Curves – UCAR PG ADF (10° Buffer) – AMIL Data

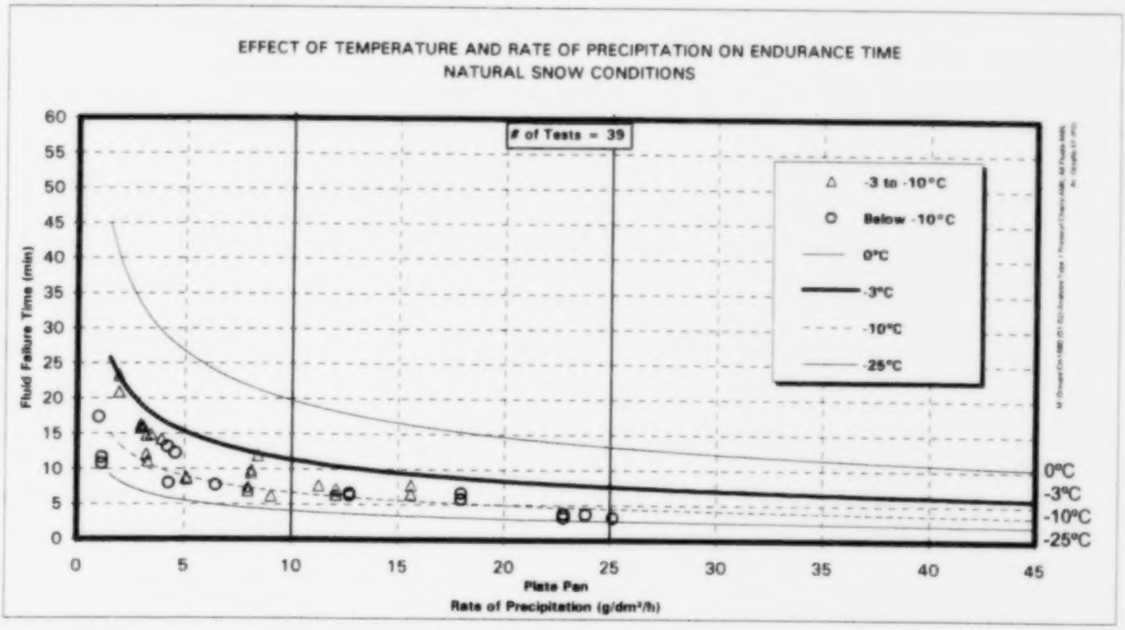

Figure 4.32: Regression Curves – Octaflo EF (10° Buffer) – AMIL Data

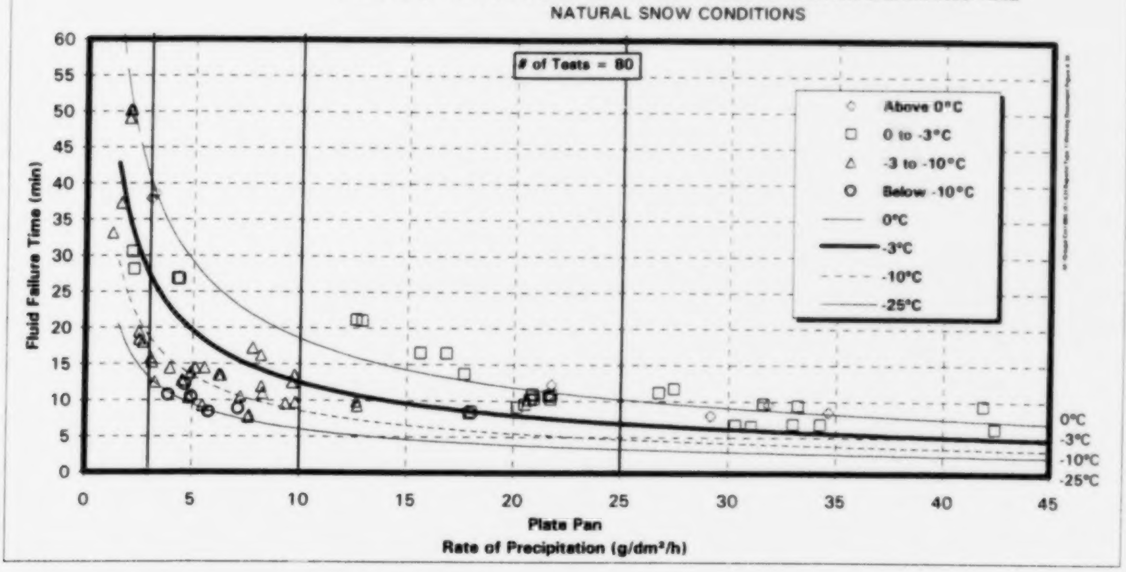

Figure 4.33: Type I Tests (10° Buffer) on Boxes – APS Data

Table 4.12: Type I Tests (10° Buffer) – APS Results

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
°C	°F	FROST	FREEZING FOG	LIGHT SNOW	MODERATE SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
above -3	above 27			0:12-0:27	0:06-0:12				
-3 to -10	27 to 14			0:08-0:18	0:04-0:08			CAUTION No holdover time guidelines exist	
below -10	below 14			0:06-0:13	0:03-0:06				

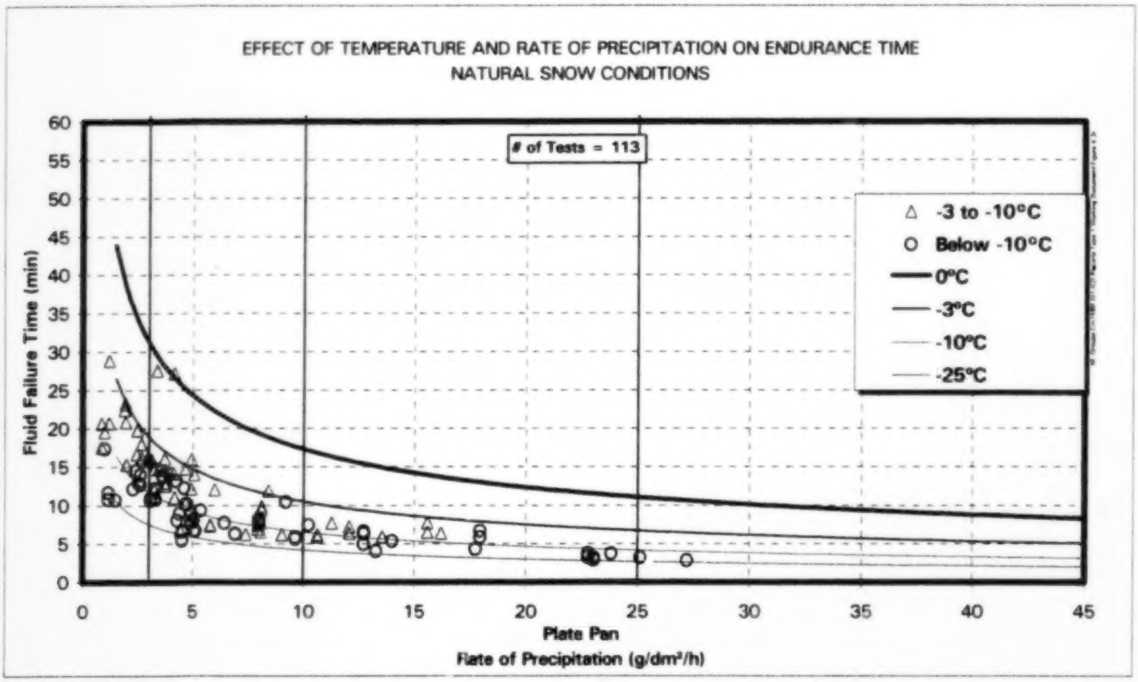

Figure 4.34: Type I Tests (10° Buffer) on Boxes – AMIL DATA

The number of values obtained by AMIL were rounded down, and these results are summarized in Table 4.13. AMIL did not have results above -3°C; therefore, the data presented in the two upper cells of the HOT table are extrapolations from the regression analysis based on lower temperatures. The numbers in the *light snow* column are also calculated using precipitation rates obtained from TC.

Table 4.13: Type I Tests (10° Buffer) – AMIL Results

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
°C	°F	FROST	FREEZING FOG	**LIGHT SNOW**	**MODERATE SNOW**	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
above -3	above 27			0:10-0:18	0:06-0:10				**CAUTION No holdover time guidelines exist**
-3 to -10	27 to 14			0:06-0:11	0:04-0:06				
below -10	below 14			0:04-0:07	0:02-0:04				

4.5.6 APS and AMIL Combined Endurance Time Results

The results of tests gathered by APS and AMIL using 10°C buffer fluid applied on boxes were combined and are given in Figure 4.35.

The best-fit curves were produced for the lowest temperature intervals of the HOT tables and are based on all the data points on the chart. For discussion purposes, the chart presented in Figure 4.35 distinguishes between the values obtained by APS and those from AMIL.

Comparing Table 4.12 and Table 4.13, values obtained by APS tended towards higher holdover times than those obtained by AMIL in comparable conditions. Also, for temperatures above -3°C, the data is based exclusively on test results from APS. The regression curves generated from the combined (APS and AMIL) data sets produced the HOT values shown in Table 4.14.

In the -3 to -10°C temperature range, the two data sets present the most overlap, but overall the entire range of temperatures in the HOT table was addressed during testing, by APS, AMIL or both.

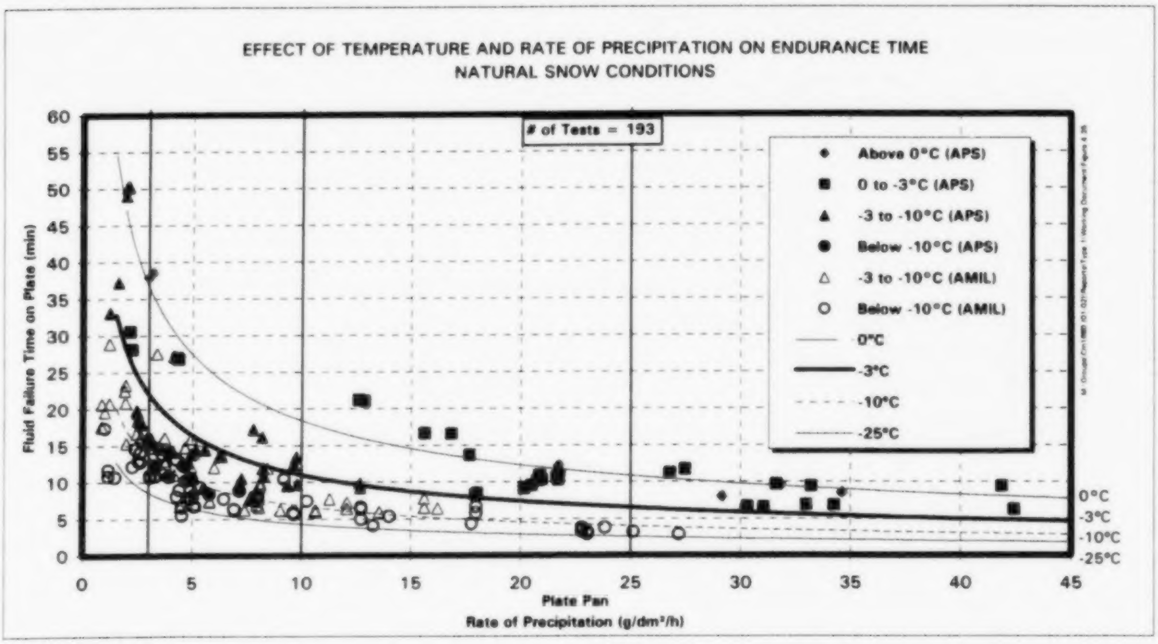

Figure 4.35: Type I Tests (10° Buffer) on Boxes – APS and AMIL Combined

Table 4.14: Type I Tests (10° Buffer) – APS and AMIL Combined Results

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
°C	°F	FROST	FREEZING FOG	LIGHT SNOW	MODERATE SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
above -3	above 27			0:11-0:22	0:06-0:11				
-3 to -10	27 to 14			0:06-0:13	0:04-0:06			**CAUTION No holdover time guidelines exist**	
below -10	below 14			0:04-0:08	0:02-0:04				

A summary of all HOT values from Toulouse data and all the tests done during the winter of 2001-02 by APS and AMIL using 10° Buffer Type I fluids in natural snow is presented in Table 4.15.

Table 4.15: Summary of Results

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
		Light Snow			Moderate Snow			
°C	°F	APS	AMIL	APS+AMIL	TOULOUSE	APS	AMIL	APS+AMIL
above -3	above 27	0:12-0:27	0:10-0:18	0:11-0:22	0:07-0:12* 0:03-0:06**	0:06-0:12	0:06-0:10	0:06-0:11
-3 to -10	27 to 14	0:08-0:18	0:06-0:11	0:06-0:13	0:03-0:06	0:04-0:08	0:04-0:06	0:04-0:06
below -10	below 14	0:06-0:13	0:04-0:07	0:04-0:08	0:02-0:04	0:03-0:06	0:02-0:04	0:02-0:04

* Holdover times calculated for the 'Above 0°C' temperature range.

** Holdover times calculated for the '0 to -10°C' temperature range.

In Table 4.15, the Toulouse numbers are included for comparison purposes only. The "APS + AMIL" column shows the numbers produced from the combined data set. At the SAE HOT Workgroup meeting held in Montreal in May 2002, it was decided that the combined results should be rounded down to the nearest whole number.

The numbers presented are calculated for TC's ranges of precipitation rates and temperatures. The data set is based on the combined results from APS and AMIL and covers a wide range of temperatures and precipitation rates. Thus, the data can be applied to any temperature and precipitation rate that the regulators choose for snow. To support this, Table 4.16 shows the holdover times calculated for different outside air temperatures and precipitation rates. The results are generated from the combined data set (193 data points) using regression analysis.

4.5.7 Evaluation of Endurance Times of Fluid Heated Below 60°C

Item 5.7.1 of the Work Statement (an excerpt from the Work Statement is provided in Appendix A) specifies the need to conduct a feasibility study to identify the utility of producing a Type I HOT table that reflects field operations with fluid temperatures lower than 60°C at the spray nozzle. Some operators have indicated that some of their deicing vehicles are unable to deliver fluid heated to the desired temperature of at least 60°C at the nozzle. However, because concerns had not been raised at the industry meetings held in Montreal in November 2001, these tests were not conducted. It would be helpful to conduct a survey at several airports in an attempt to collect data on actual fluid temperatures used by deicing operators.

Table 4.16: Regression Generated Endurance Times (min) from the Combined Data Set

OAT (°C)	PRECIPITATION RATE (g/dm²/h)										
	1	2	3	4	5	10	15	20	25	50	100
0	69.0	46.3	36.7	31.1	27.4	18.4	14.5	12.3	10.8	7.3	4.9
-1	55.0	36.9	29.3	24.8	21.8	14.6	11.6	9.8	8.6	5.8	3.9
-2	46.9	31.5	24.9	21.1	18.6	12.5	9.9	8.4	7.4	4.9	3.3
-3	41.4	27.8	22.0	18.6	16.4	11.0	8.7	7.4	6.5	4.4	2.9
-4	37.4	25.1	19.9	16.8	14.8	9.9	7.9	6.7	5.9	3.9	2.6
-5	34.3	23.0	18.2	15.5	13.6	9.1	7.2	6.1	5.4	3.6	2.4
-6	31.8	21.4	16.9	14.3	12.6	8.5	6.7	5.7	5.0	3.4	2.3
-7	29.8	20.0	15.8	13.4	11.8	7.9	6.3	5.3	4.7	3.1	2.1
-8	28.1	18.9	14.9	12.7	11.1	7.5	5.9	5.0	4.4	3.0	2.0
-9	26.6	17.9	14.2	12.0	10.6	7.1	5.6	4.8	4.2	2.8	1.9
-10	25.4	17.0	13.5	11.4	10.1	6.8	5.3	4.5	4.0	2.7	1.8
-11	24.3	16.3	12.9	10.9	9.6	6.5	5.1	4.3	3.8	2.6	1.7
-12	23.3	15.6	12.4	10.5	9.2	6.2	4.9	4.2	3.7	2.5	1.6
-13	22.4	15.0	11.9	10.1	8.9	6.0	4.7	4.0	3.5	2.4	1.6
-14	21.6	14.5	11.5	9.7	8.6	5.7	4.6	3.9	3.4	2.3	1.5
-15	20.9	14.0	11.1	9.4	8.3	5.6	4.4	3.7	3.3	2.2	1.5
-16	20.2	13.6	10.8	9.1	8.0	5.4	4.3	3.6	3.2	2.1	1.4
-17	19.6	13.2	10.4	8.8	7.8	5.2	4.1	3.5	3.1	2.1	1.4
-18	19.1	12.8	10.1	8.6	7.6	5.1	4.0	3.4	3.0	2.0	1.3
-19	18.6	12.5	9.9	8.4	7.4	4.9	3.9	3.3	2.9	2.0	1.3
-20	18.1	12.1	9.6	8.2	7.2	4.8	3.8	3.2	2.8	1.9	1.3
-21	17.6	11.8	9.4	8.0	7.0	4.7	3.7	3.2	2.8	1.9	1.2
-22	17.2	11.6	9.2	7.8	6.8	4.6	3.6	3.1	2.7	1.8	1.2
-23	16.8	11.3	9.0	7.6	6.7	4.5	3.5	3.0	2.6	1.8	1.2
-24	16.5	11.1	8.8	7.4	6.5	4.4	3.5	2.9	2.6	1.7	1.2
-25	16.1	10.8	8.6	7.3	6.4	4.3	3.4	2.9	2.5	1.7	1.1

4.5.8 Lower Precipitation Rate Limit for Light Snow

TC has selected a lower limit of 3 g/dm^2/h to be used for the *light snow* column; however, the FAA selected a lower limit of 5 g/dm^2/h. The TC position has taken into consideration the very low rates that are experienced in Northern Canada at low temperatures. The FAA position, which results in shorter endurance times at the lower limit, is balanced by the FAA rule that adds 5 minutes to a pre-take off contamination check.

At this time, it appears that each agency will publish its own table with different times for *light snow*.

Table 4.17 shows the SAE Type I Fluid Holdover Time Table to be published by TC. Note 6 reports the precipitation rate limits used for *light snow*.

Using the rate of 3 g/dm^2/h as the lower precipitation rate limit for light snow, the TC holdover times for light snow are as follows:

a) Above -3°C: 11 to 22 minutes;
b) -3°C to -10°C: 6 to 13 minutes; and
c) Below -10°C: 4 to 8 minutes.

Using the rate of 5 g/dm^2/h as the lower precipitation rate limit for light snow, the FAA holdover times for light snow are as follows:

a) -3°C and above: 11 to 16 minutes;
b) Below -3°C to -6°C: 8 to 13 minutes;
c) -7 to -10°C: 6 to 10 minutes; and
d) Below -10°C: 4 to 6 minutes.

Regardless of the difference in the rate selected as the lower limit for *light snow*, both TC and the FAA are now proposing more conservative holdover times than the historical values (prior to 2000).

A new technology in development by NCAR would help in deciding between 3 g/dm^2/h versus 5 g/dm^2/h. The technique involves leaving a hot plate outside under precipitation conditions. As the precipitation falls on it, the plate cools down. This new technology converts the power required to heat the plate to a constant temperature, in liquid water equivalent precipitation rate. NCAR believes that the technology is already viable. Tests with the hot plate conducted by APS should be done concurrently with tests using plate pans to verify the accuracy of the hot plate method.

Table 4.17: Transport Canada Type I Fluid Holdover Time Table

TABLE 1S-3gm
SAE TYPE I[5] FLUID HOLDOVER GUIDELINES FOR WINTER 2002-2003
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (minutes)							
°C	°F	Frost [2]	Freezing Fog	Light Snow[1]	Moderate Snow [1]	Freezing Drizzle [3]	Light Freezing Rain	Rain On Cold Soaked Wing	Other [4]
above -3	above 27	45	11 - 17	11 - 22[6]	6 - 11	9 - 13	2 - 5	2 - 5	**CAUTION :** **No holdover time guidelines exist**
-3 to -10	27 to 14	45	6 - 10	6 - 13[6]	4 - 6	5 - 8	2 - 5		
below -10	below 14	45	5 - 9	4 - 8[6]	2 - 4				

°C = Degrees Celsius
°F = Degrees Fahrenheit
OAT = Outside Air Temperature
FP = Freezing Point

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 L/m^2 (2 gal./100 sq.ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.
6 The light snow range is based on precipitation rates from 1.0 mm/hr to 0.3 mm/hr liquid water equivalent

CAUTIONS:

- **The time of protection will be shortened in severe weather conditions, heavy precipitation rates or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **Fluids used during ground deicing do not provide ice protection during flight.**

4.5.9 Fluid Freezing Point vs. Plate Temperature Analysis

As mentioned in Subsection 4.3.2, APS logged test surface temperatures with thermistor probes mounted on each of the three boxes and two plates. APS also measured fluid dilution rates at the 15 cm line, using a Misco 10431VP refractometer. These measurements were conducted to determine the concentration of the fluid on the test surface until it failed. The final Brix was always recorded at failure. The Brix readings were then converted into fluid freezing point (FFP) values using the manufacturer's transformation charts.

The results from APS testing are shown in Figure 4.36 and Figure 4.37 for ethylene-based fluid and propylene-based fluid, respectively.

The data points on the charts represent values of the fluid freezing point and the test surface temperature, at failure. The diagonal line indicates the imaginary correlation between the two parameters. The fluid is expected to fail when it reaches its freezing point (horizontal axis of the charts). Ideally, if the failures were called consistently and no other factors were influencing the process, all the data points on the chart would lie on the diagonal line. As observed on the two charts, the recorded values were generally close to the desired line, indicating that the failure calls made by APS were consistent and reliable.

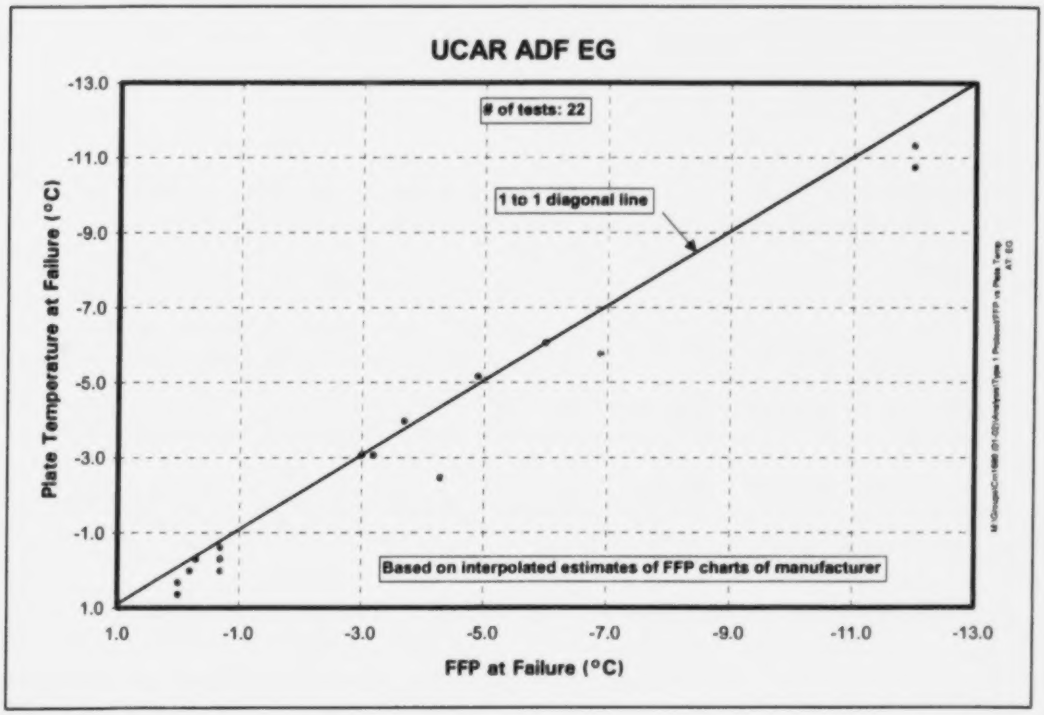

Figure 4.36: Fluid Freeze Point vs. Plate Temperature at Failure – UCAR ADF EG

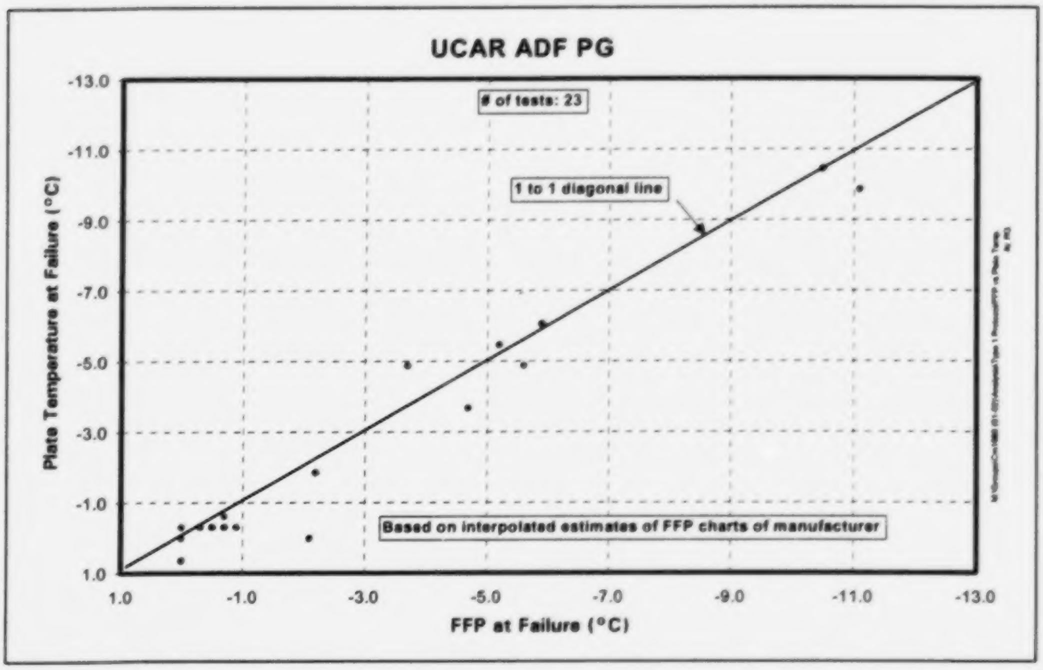

Figure 4.37: Fluid Freeze Point vs. Plate Temperature at Failure – UCAR ADF PG

4.5.10 Full-Scale Wing Tests in Comparison with 2001-02 Winter Results

APS and AMIL have conducted 193 outdoor snow tests with Type I fluids using the empty aluminum box. Using a multi-variable regression approach, the data set was analysed and the results are presented in Figure 4.37

In previous winters, APS has conducted full-scale tests on aircraft wings at different locations. Tests on each aircraft consisted of spraying the wing with heated fluid and observing the fluid while the wing gradually cooled, until complete fluid failure. The results from these tests indicate the importance of the wing leading edge when considering fluid endurance times on actual wings.

Summaries of the full-scale tests conducted by APS over several past winters are shown in Tables 4.18 to 4.20.

As observed in these tables, the failure progress was recorded at three important moments: first failure, 10 percent failure, and final failure. For the 1994-95 and 1996-97 winters, complete failure was called when 25 percent of the wing area was contaminated. For the tests conducted during the winter of 1999-2000, complete failure was announced when the failed fluid covered the entire wing area.

The data points corresponding to first failure and 10 percent failure were superimposed on the chart presenting the combined APS and AMIL regression curves generated from the box data, as shown in Figure 4.38 and Figure 4.39.

Table 4.18: Aircraft Full-Scale Tests Conducted in 1994-95

ID #	Test Location	Date	A/C Type	A/C Wing	Fluid Name	Air Temp (°C)	Precip. Rate (g/dm^2/h)	Wind Head/Tail/ Cross	Wind Direct. (deg.)	Wind Speed (km/h)	A/C Orient. (E of N) (deg.)	Aircraft Failure 1st Fail LE/TE (min)	10% LE/TE (min)	25% LE/TE (min)	Precip. Type
L2	YUL	Mar-06-95	DC-9	Strbd	XL54	-7	21	head	36	15	63	8	10	12	snow
L4	YUL	Mar-06-95	DC-9	Strbd	XL54	-7	7	head	36	14	63	14	23	25	snow
L5	YUL	Mar-06-95	DC-9	Port	XL54	-7	6	head	32	10	63	8	12	16	snow
L8	YUL	Mar-09-95	DC-9	Strbd	XL54	-7	9	cross	324	12	17	8	11	13	snow
L9	YUL	Mar-09-95	DC-9	Strbd	XL54	-7	6	cross	326	9	17	10	12	13	snow
T3	YYT	Mar-01-95	DC-9	Port	XL54	-5	7	head	60	28	80	7	7	14	snow
T3	YYT	Mar-01-95	DC-9	Strbd	XL54	-5	7	head	60	28	80	7	9	11	snow
T4	YYT	Mar-01-95	DC-9	Port	XL54	-6	15	head	60	26	80	7	8	10	snow
T4	YYT	Mar-01-95	DC-9	Strbd	XL54	-6	15	head	60	26	80	6	8	10	snow
T5	YYT	Mar-01-95	DC-9	Port	XL54	-7	17	head	60	24	80	8	8	9	snow
Z1	YYZ	Feb-21-95	B-737	Strbd	XL54	0	17	head	347	4	295	8	10	17	snow
Z2	YYZ	Feb-21-95	B-737	Strbd	XL54	2	2	cross	50	4	295	23	24	70	snow

Table 4.19: Aircraft Full-Scale Tests Conducted in 1996-97

ID #	Test Location	Date	A/C Type	A/C Wing	Fluid Name	Air Temp (°C)	Precip. Rate (g/dm^2/h)	Wind Head/Tail/ Cross	Wind Direct. (deg.)	Wind Speed (km/h)	A/C Orient. (E of N) (deg.)	Wing First Fail (min)	Wing 10% Fail (min)	Wing 25% Fail (min)	Wing Rate First g/dm^2/h	Wing Rate 10% g/dm^2/h	Wing Rate 25% g/dm^2/h
1	YUL	Jan-16-97	B-737	Strbd	XL54	-0.2	6.6	cross	182	14	55	36	43	45	2.2	5.5	6.3
2	YUL	Jan-16-97	B-737	Port	XL54	-0.3	9.4	cross	183	13	55	30	33	35	3.3	5.1	6.1
3	YUL	Jan-16-97	B-737	Strbd	XL54	-1.2	7.2	cross	173	11	56	8	12	N/F	9.2	6.9	
4	YUL	Jan-16-97	B-737	Port	XL54	-1.1	6.3	cross	175	11	55	8	N/F	N/F	7.1		
9	YUL	Jan-25-97	B-737	Port	XL54	-1.6	11.3	cross	135	18	240	10	14	15	10.5	9.2	9.2
14	YUL	Jan-28-97	B-737	Strbd	XL54	-4.9	20.8	tail	156	11	310	4	6	7	20.8	20.9	21.1
15	YUL	Jan-28-97	B-737	Strbd	XL54	-4.5	12.3	tail	155	11	310	6	9	14	12.0	11.3	11.4
16	YUL	Jan-28-97	B-737	Strbd	XL54	-4.0	29.9	tail	171	11	310	4	7	10	12.8	24.0	30.3
20	YUL	Feb-05-97	F100	Strbd	XL54	-1.9	16.8	tail	97	7	275	5	9	12	23.2	23.2	20.1
21	YUL	Feb-05-97	F100	Strbd	XL54	-1.6	19.6	tail	109	9	275	6	7	9	16.7	16.9	17.2
22	YUL	Feb-05-97	F100	Port	XL54	-1.4	14.4	tail	108	9	275	8	9	10	15.2	15.1	15.1
23	YUL	Feb-05-97	F100	Strbd	XL54	-1.4	13.6	tail	105	9	275	6	8	10	14.4	15.7	16.4
30	YUL	Mar-06-97	F100	Port	XL54	-3.2	8.0	head	52	16	50	9	10	12	4.0	4.0	4.9
31	YUL	Mar-06-97	F100	Port	XL54	-3.8	6.1	head	49	17	50	6	9	14	9.6	9.2	8.4
32	YUL	Mar-06-97	F100	Port	XL54	-4.1	16.4	cross	51	20	310	3	4	6	20.0	17.6	16.4
33	YUL	Mar-06-97	F100	Strbd	XL54	-4.2	15.5	cross	51	20	310	9	10	11	15.9	16.1	16.3

M:\Groups\Cm 1680(01-02)\Reports\Type I\Working Document\Table 4.20

Table 4.20: RJ Full-Scale Tests Conducted in 1999-2000

ID #	Date	A/C Wing	Fluid Name	Precip. Rate (g/dm²/h)	Wind Head/Tail/ Cross	Air Temp (°C)	Wind Speed (km/h)	Wing First Fail (min)	Wing 10% Fail * (min)	Wing Complete Fail ** (min)	Precip. Type
1	Jan-26-00	Port	XL54	3.0	Cross	-6.6	23	37	41	54	snow
2	Jan-26-00	Strbd	XL54	3.0	Cross	-6.6	22	37	40	48	snow
3	Jan-26-00	Port	XL54	9.1	Cross	-6.6	22	7	11	15	snow
4	Jan-26-00	Strbd	XL54	9.1	Cross	-6.6	21	7	12	14	snow
5	Jan-26-00	Port	XL54	24.0	Tail	-6.8	18	4	8	14	snow
6	Jan-26-00	Strbd	XL54	24.0	Tail	-6.8	17	4	6	10	snow
8	Jan-26-00	Strbd	XL54	13.8	Head	-6.9	15	5	7	15	snow

* FAILED FLUID OVER 10% OF WING AREA

** FAILED FLUID OVER ENTIRE WING AREA

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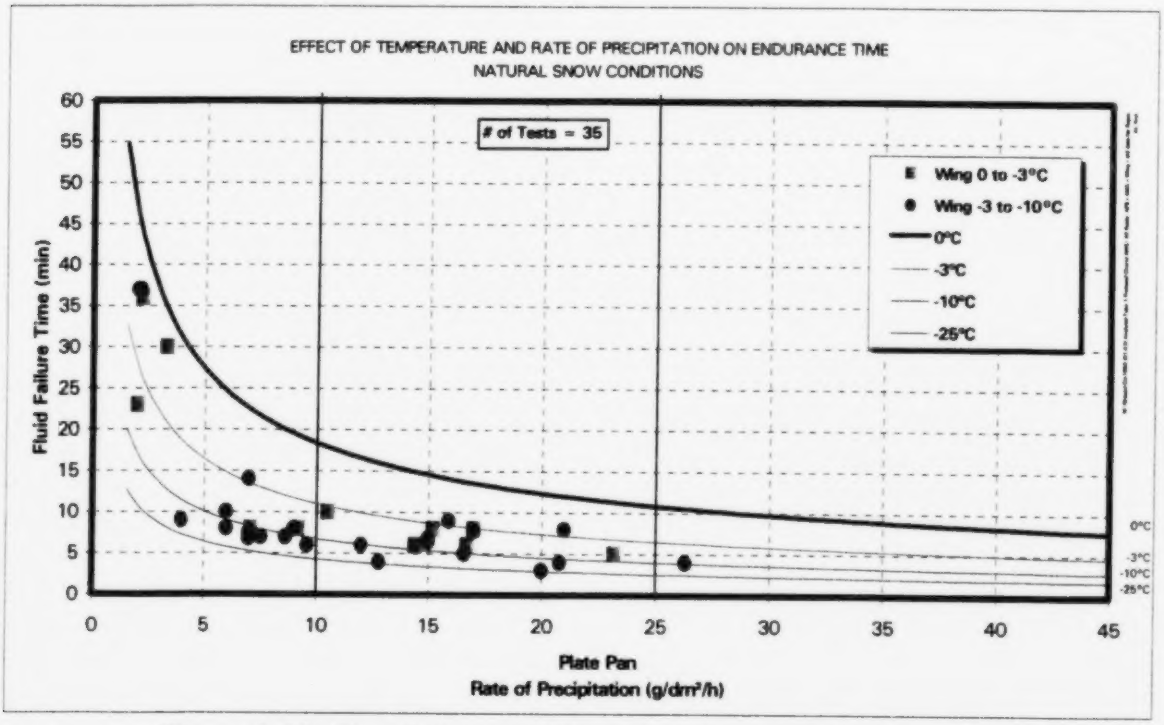

Figure 4.38: First Failure on Wing Superimposed on Box Data

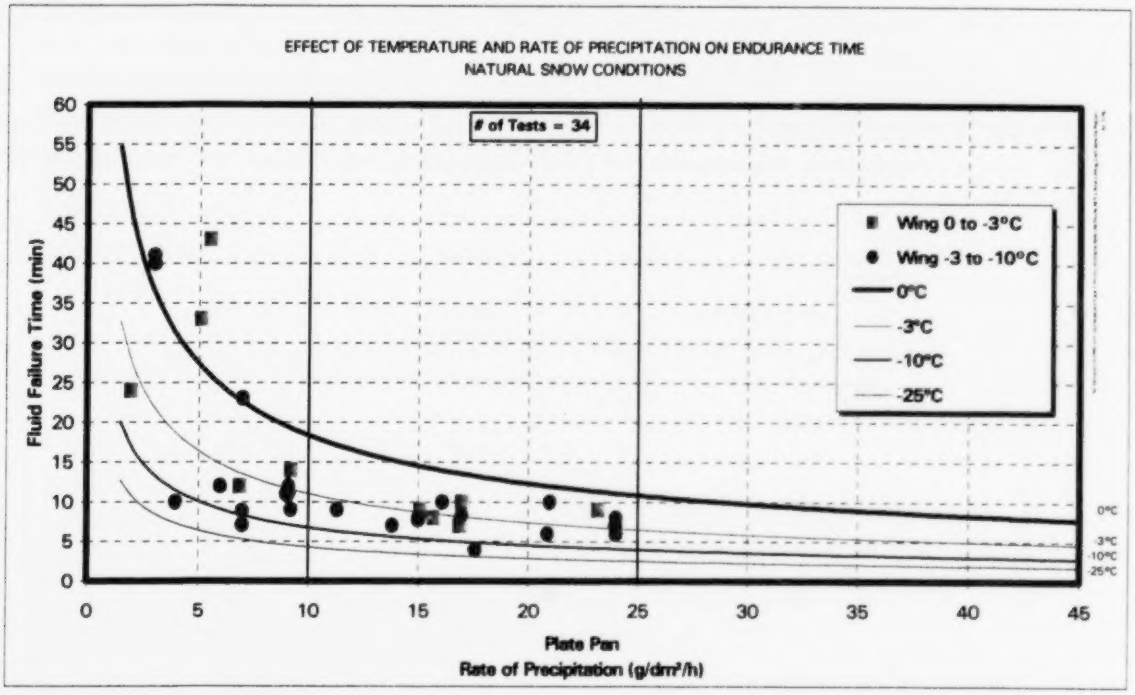

Figure 4.39: 10 Percent Wing Failure Superimposed on Box Data

As observed for each temperature interval in Figure 4.39, the data points are typically above the corresponding regression curve. This indicates that the HOT values calculated from the combined data set obtained by APS and AMIL are conservative and can be considered a good representation of the real field operational holdover times.

4.5.11 CRDA Data Points Comparison with 2001-02 Winter Results

The 6 to 15 minute Type I holdover time for Type I fluids has been used for the past 10 years. The Cooperative Research and Development Agreement (CRDA) was issued by the FAA as a result of discussions between the FAA Technical Center and American Eagle Airlines to provide actual snow condition data on failure times of Type I deicing fluids to the SAE Holdover Time Subcommittee. The purpose of the data collection was to provide SAE with scientific data on which a decision to continue to use the current holdover times for Type I can be justified. To assess the validity of the 6 to 15 minute holdover time values, a study was carried out at three locations (Quebec City, Lacrosse, and Dubuque) during real field deicing operations. APS was asked to provide training on how to conduct the tests.

The tests consisted of measuring precipitation rates during real field deicing operations. The test stand used for testing is shown in Photo 4.4.

A total of nine tests were conducted. The data points were superimposed on the chart presenting the combined APS and AMIL regression curves, as shown in Figure 4.40.

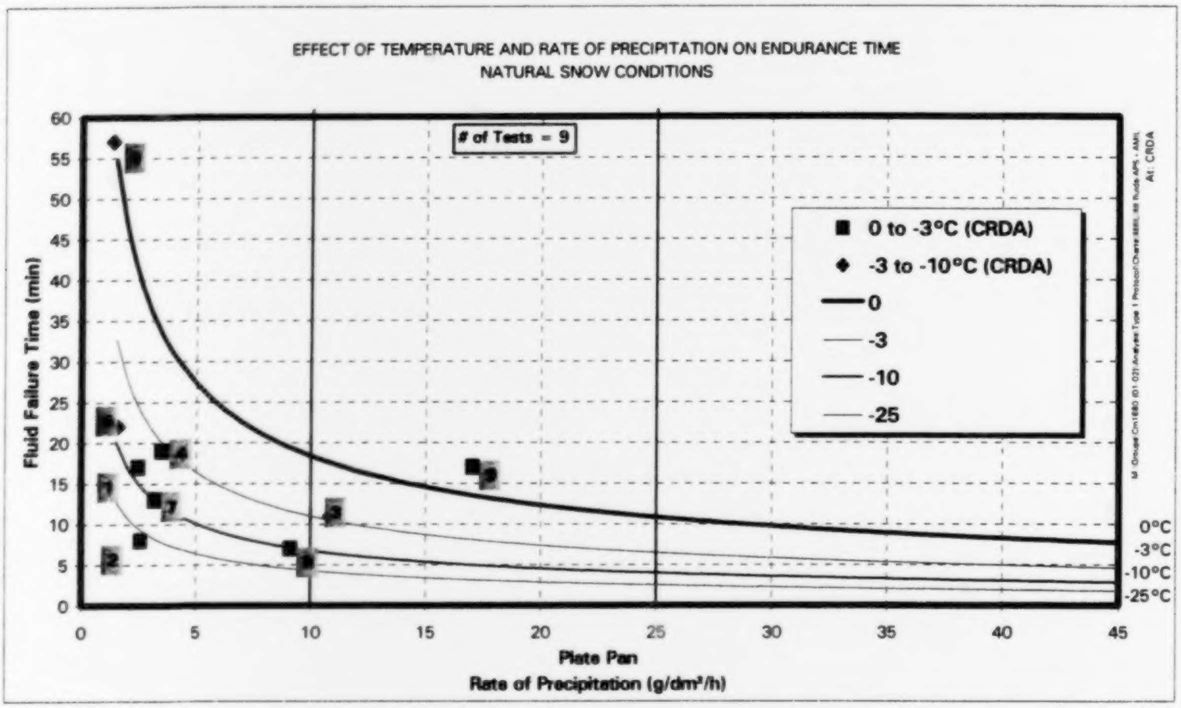

Figure 4.40: CRDA Data Points

Each CRDA data point on the chart is represented by two coordinates: the time after which the aircraft took-off (vertical axis) and the intensity of snow precipitation (horizontal axis). Provided the wing was uncontaminated at takeoff, the actual endurance times would have been higher than the times currently recorded.

As observed on the chart, the test results were scattered. Analysis of the data was difficult because the wing condition at takeoff was unknown. Points 3, 5, 6, and 9 indicate that the holdover times could be longer than those obtained using the empty aluminum box procedure (assuming that the precipitation rate is correct and the wing is free from contamination). From points 1, 2, 4, 7, and 8, it is possible to conclude that the holdover times from testing with the newly developed Type I protocol are longer than the endurance times in real field deicing operations.

The scatter of results may be explained by some inconsistencies while testing. For example, the time between taxiing the aircraft into position and the measurement of rates was occasionally delayed; thus the precipitation rate measured on the wing could have been different from the precipitation rate measured on the test stand.

For further testing, it would be useful to run endurance tests on boxes at the same time to give a better estimate of the validity of the data.

4.5.12 Confidence Level Analysis of the Combined Data Set

4.5.12.1 Background

As described in Subsection 4.5.2, the method used for analyzing the test results is the Multi-Variable Regression Protocol. One question in particular may arise: what is the degree of confidence that the regression curve represents the true mean of all the values analysed?

The confidence interval is the interval that measures the overall quality of the curve. A large confidence interval around the slope indicates that the distribution for the coefficient is broad and therefore the estimate of it is not very precise.

The confidence interval is explained graphically in Appendix L.

4.5.12.2 Analysis of APS and AMIL data set

Using the example presented in Appendix L, the combined data set from APS and AMIL was examined for a confidence interval of 95 percent. To keep the chart readable, the total number of data points was analyzed only for the -3°C temperature curve.

Altogether, APS and AMIL conducted 193 Type I tests using the new Type I protocol. The data points obtained for all these tests are presented in Figure 4.41. The upper and the lower 95 percent confidence interval limits are also indicated on the chart.

By multiplying the total number of points (APS+AMIL) by two, which hypothetically is similar to an additional testing season, the confidence intervals narrow down, thereby increasing the confidence of the best-fit curve. Continuing the same theoretical analysis, by adding four testing seasons, the confidence interval limits approach each other even more closely. Table 4.21 illustrates the results from these calculations, for an outside air temperature of -3°C.

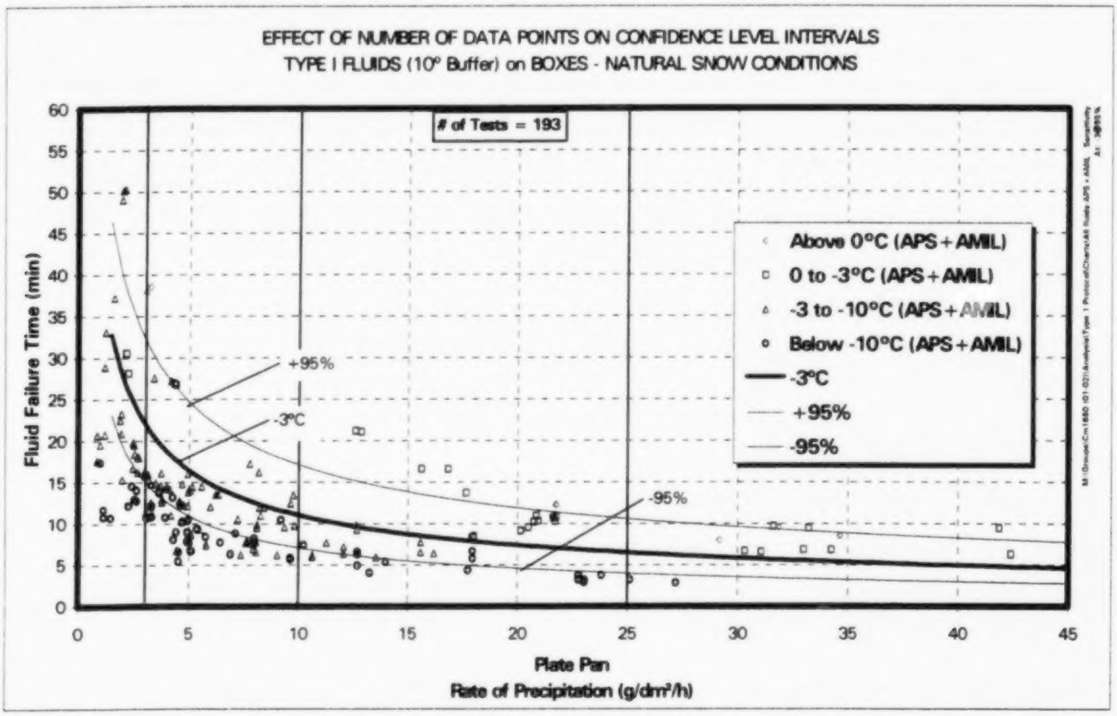

Figure 4.41: Original Data set (APS + AMIL) with Confidence Interval for -3°C

Table 4.21: Effect of the Number of Test Seasons on the Lower Limit of the 95% Confidence Interval, -3°C

Number of Testing Seasons	Precipitation Rate (g/dm²/h)			# of Data Points
	3	10	25	
	Holdover Time (min)			
Current Data set	22	11	6	193
Lower Limit of the Current Data set	15	7	4	193
Lower Limit of the Current Data set + one additional year	16	8	4	386
Lower Limit of the Current Data set + four additional years	18	9	5	965

By increasing the number of test seasons, according to the trend presented in Table 4.21, the confidence level increases. This analysis also infers that by running tests for four more years, the 95th percentile confidence interval would not change significantly.

It is important to note that the calculations for subsequent years are based on the same data set. It is quite possible that tests performed in the future may yield different results, which would give rise to confidence intervals that vary from those hypothesized above.

Photo 4.1: APS Test Site

Photo 4.2: APS Test Site – Test Stand Used for Type I Endurance Time Tests

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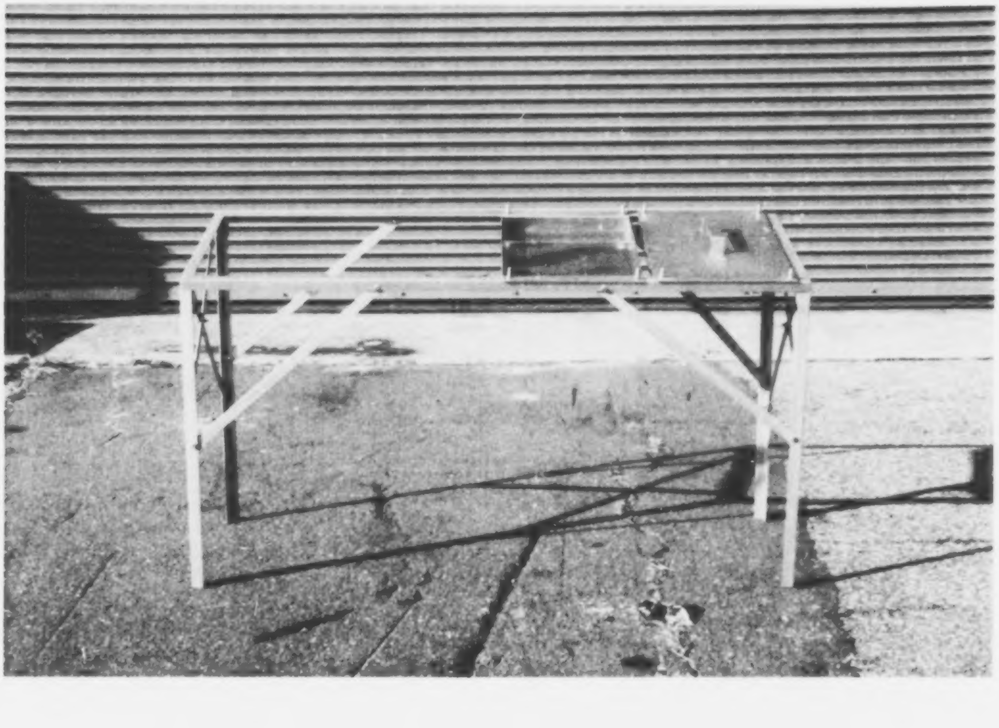
Photo 4.3: Environment Canada's Weather Observation Station at Dorval Airport

Photo 4.4: Test Stand Used for CRDA Rate Measurements



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5

5. CONTRIBUTION OF HEAT TO DILUTE SAE TYPE II/IV FLUID ENDURANCE TIMES

5.1 Background

At an SAE G-12 HOT Subcommittee meeting in November 2000, discussion focused on the need to recognize the contribution of heat in the endurance time test procedure for Type I fluids. Heated Type II and IV fluids at 50/50 and 75/25 concentrations were currently being used in one-step deicing procedures, particularly in Europe. The Subcommittee recommended that the test procedure also recognize the contribution of heat and use the same box that is used in tests with the Type I fluids.

Subsequently, preliminary tests were conducted to investigate whether heat significantly influences the endurance times for Type II and Type IV fluids. Five different fluid brands were used for these exploratory tests.

5.2 Tests Conducted During the Winter of 2001-02

Four sets of preliminary comparison tests were conducted and the results are given in Table 5.1 and in Figures 5.1 to 5.4. The general test procedures are noted on the figures and are specified below:

Figure 5.1:	Outdoor tests in snow compared endurance times for Type II and IV fluids for the standard test procedure using plates (1.0 L of fluid applied at ambient OAT) and the new Type I test procedure using boxes (0.5 L at 60°C).
Figure 5.2:	Indoor laboratory tests at NRC in December 2001 compared endurance times using the old Type I procedure on plates (1.0 L at 20°C) to a proposed lab procedure on boxes (0.25 L at 60°C).
Figure 5.3:	Indoor laboratory tests at NRC in March 2002 compared endurance times between two boxes; one was treated with 0.5 L of Type IV fluid at 60°C and the other was treated with 1.0 L of Type IV fluid at OAT.
Figure 5.4:	Indoor laboratory tests at NRC in April 2002 compared endurance times on standard test plates; treated with Type II and Type IV fluids using 1.0 L at OAT and 1.0 L at 60°C.

Table 5.1: Log of Tests

Fluid	Dilution	Plate Endurance Time (min)	Box Endurance Time (min)		Condition, Temperature, Rate of Precipitation (g/dm^2/h)
FLUID A	50/50	6.1	9.2		Snow, 0.3°C, 31
FLUID C	75/25	36.1	38.6		Snow, -5°C, 5
FLUID C	50/50	16.2	20.3		Snow, -3.5°C, 4
FLUID A	75/25	24.2	32.3		Snow, -13.8°C, 7
FLUID A	75/25	29.1	38.5		Snow, -7.9°C, 8
FLUID A	75/25	37.8	46.0		Snow, -6.3°C, 5
FLUID A	75/25	56.0	73.8		Snow, -5°C, 5
FLUID E	75/25	55.9	124.2		Snow, -13.6°C, 4
FLUID E	75/25	30.9	128.6		Snow, -5.5°C, 2.4(Box), 1.3(Pl.)
FLUID B	50/50	13.6	18.2		Freezing Drizzle, -10°C, 13
FLUID B	50/50	23.1	38.1		Freezing Drizzle, -3°C, 13
FLUID B	50/50	12.8	15.4		Light Freezing Rain, -10°C, 13
FLUID B	50/50	19.1	34.3		Light Freezing Rain, -3°C, 13
Fluid	**Dilution**	**Box Endurance Time Cold Fluid (min)**	**Box Endurance Time Heated Fluid (min)**		**Condition, Temperature, Rate of Precipitation (g/dm^2/h)**
FLUID E	50/50	10.8	36.3		Freezing Drizzle, -3°C, 13
FLUID E	50/50	19.3	38.2		Freezing Drizzle, -3°C, 5
FLUID E	50/50	37.8	79.3		Freezing Fog, -3°C, 2
FLUID E	50/50	15.7	43.2		Freezing Fog, -3°C, 5
FLUID E	75/25	13.4	32.3		Freezing Rain, -10°C, 25
FLUID E	75/25	18.3	37.1		Freezing Rain, -3°C, 25
FLUID E	50/50	13.4	39.5		Freezing Rain, -3°C, 25
Fluid	**Dilution**	**Plate Cold Fluid (min)**	**Plate Heated Fluid (min)**	**Box Heated Fluid (min)**	**Condition, Temperature, Rate of Precipitation (g/dm^2/h)**
FLUID D	75/25	56.0	47.3		Freezing Drizzle, -10°C, 5
FLUID D	75/25	21.5	24.6		Freezing Drizzle, -10°C, 13
FLUID C	75/25	20.5	21.3		Freezing Drizzle, -3°C, 13
FLUID C	50/50	15.1	24.2	36.3	Freezing Drizzle, -3°C, 5
FLUID C	50/50	16.7	15.7		Freezing Fog, -3°C, 5
FLUID C	50/50	26.5	28.5		Freezing Fog, -3°C, 2
FLUID D	75/25	72.0	72.5		Freezing Fog, -14°C, 2
FLUID D	75/25	34.5	38.0		Freezing Fog, -14°C, 5
FLUID C	75/25	13.7	11.2		Freezing Rain, -10°C, 13
FLUID C	75/25	10.7	13.2		Freezing Rain, -10°C, 25
FLUID D	50/50	10.8	17.8		Freezing Rain, -3°C, 25
FLUID D	50/50	14.0	21.0		Freezing Rain, -3°C, 13

NB: All fluids are propylene based.

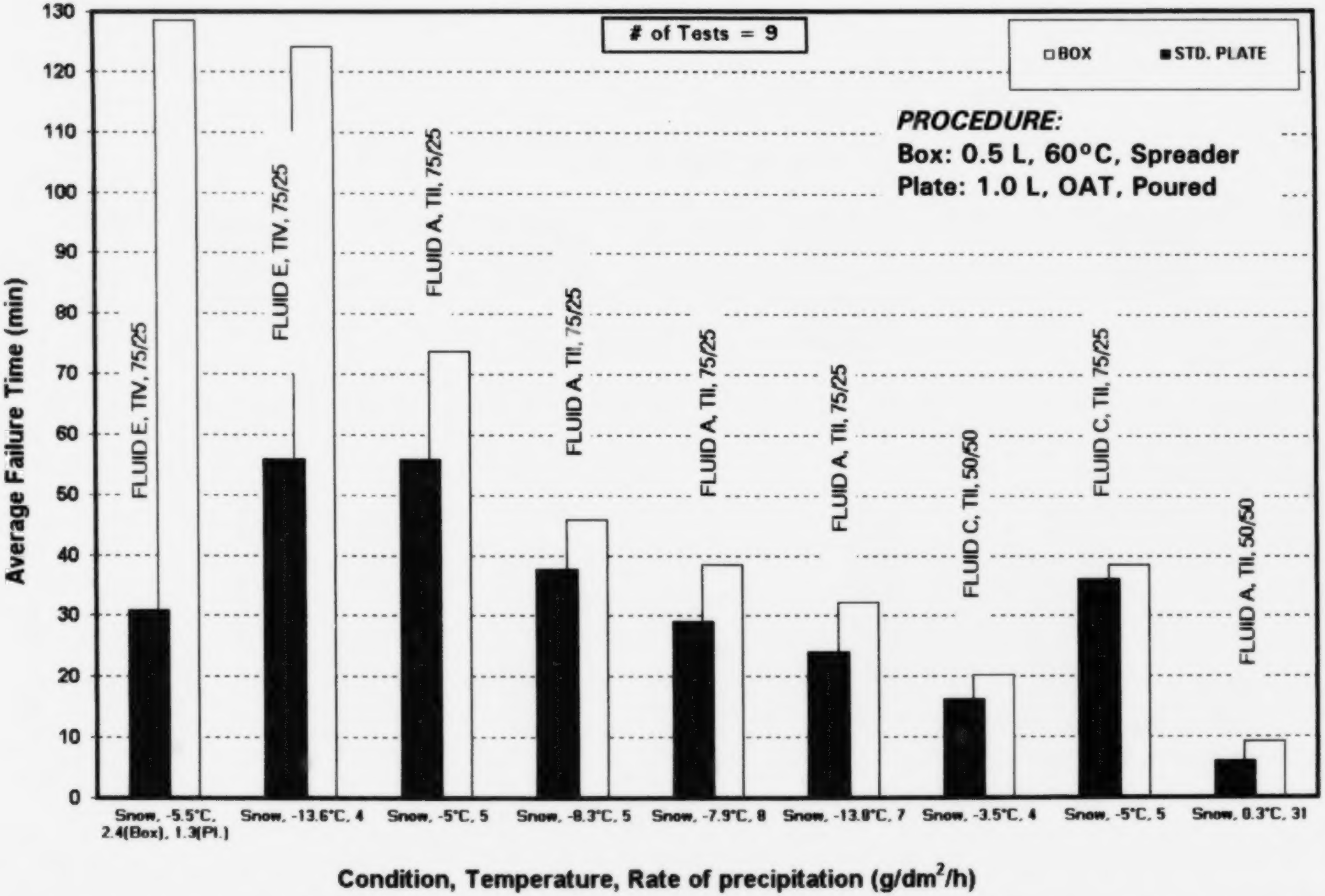

Figure 5.1: Comparison of Failure Times Between Standard Plate and Box for Diluted Type II and IV Fluids, Outdoors

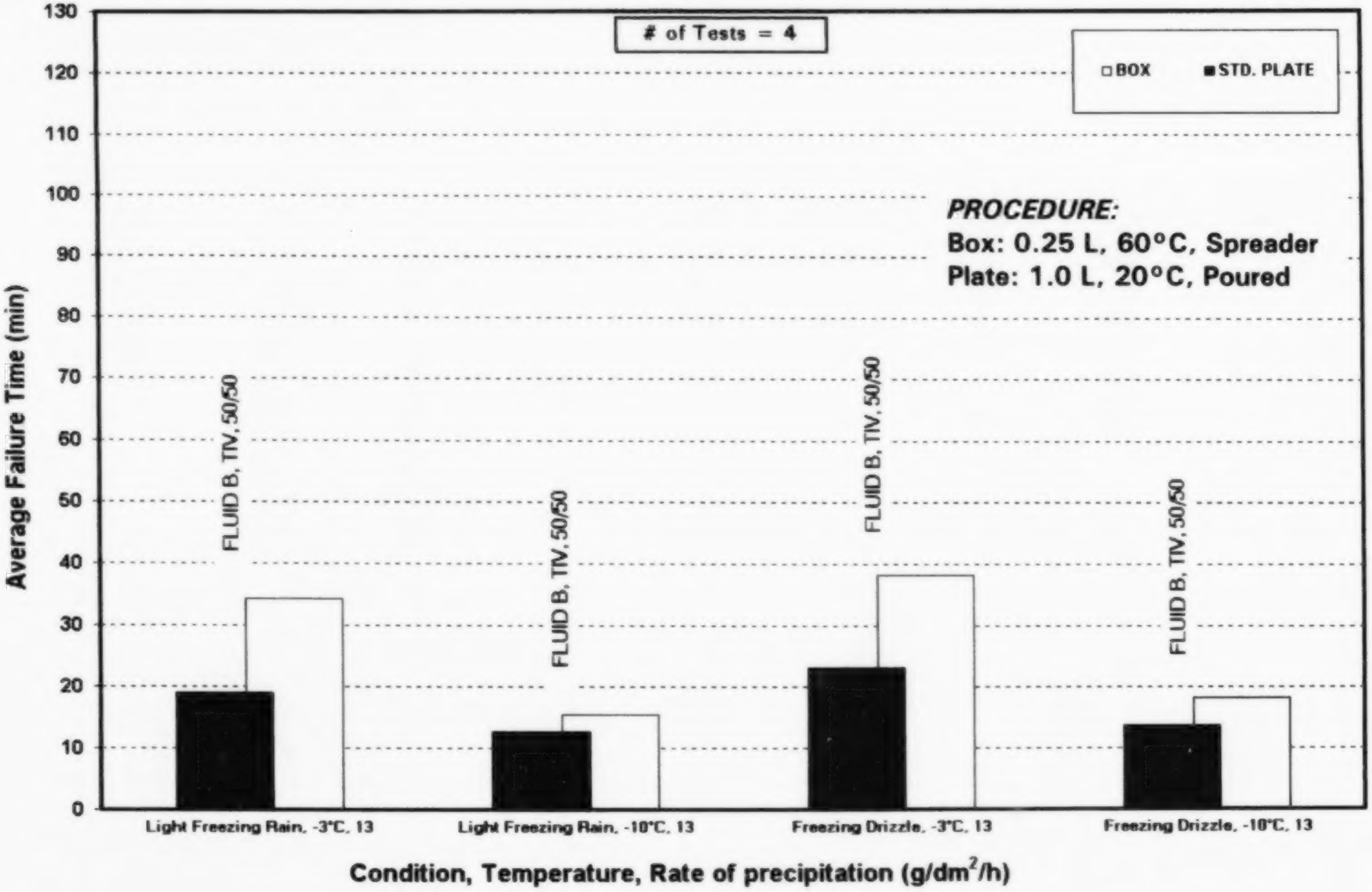

Figure 5.2: Comparison of Failure Times Between Standard Plate and Box for Diluted Type IV Fluids, Laboratory Tests

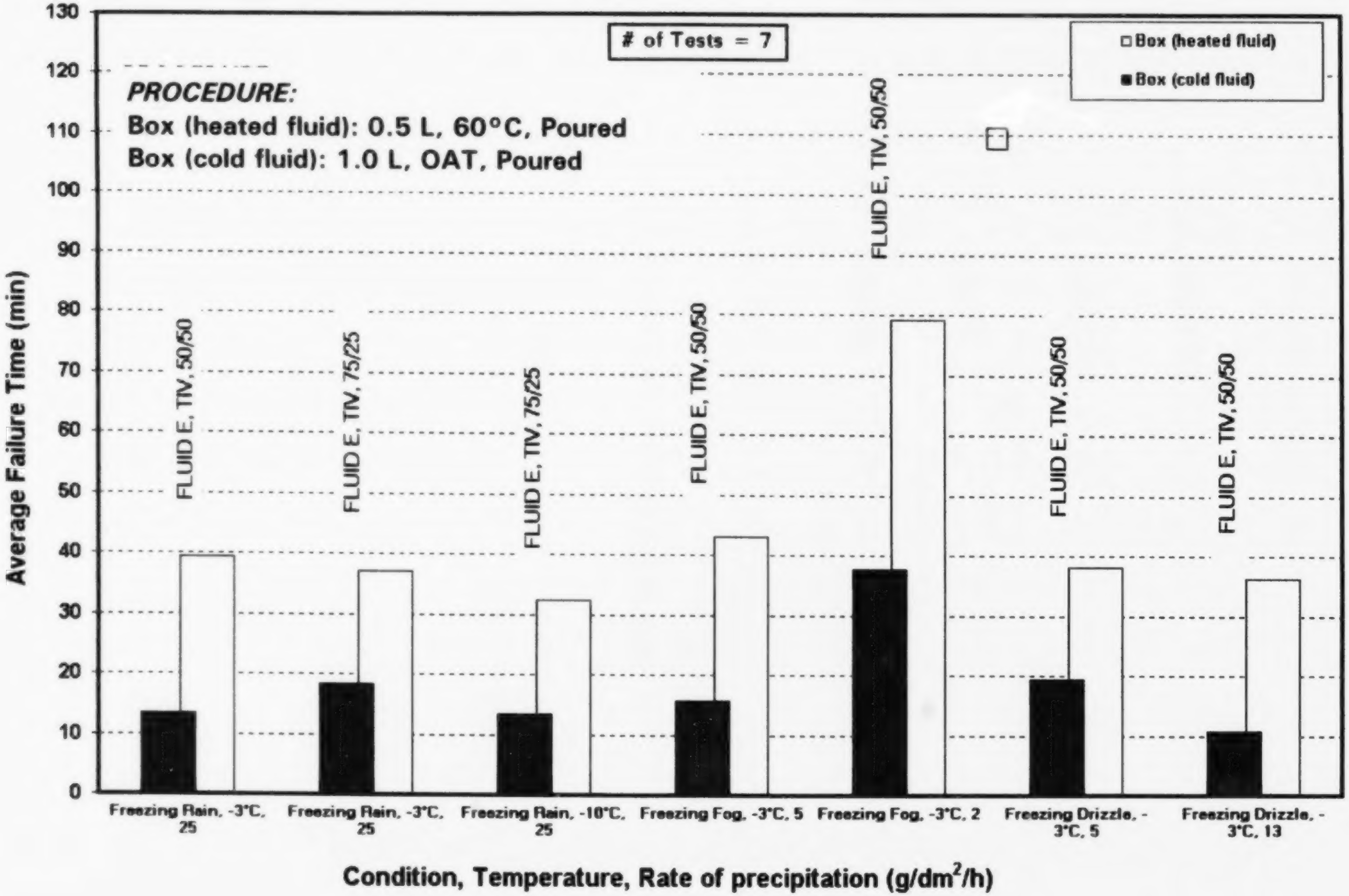

Figure 5.3: Comparison of Failure Times Between Cold Fluid and Heated Fluid on Boxes for Diluted Type IV Fluids, Laboratory Tests

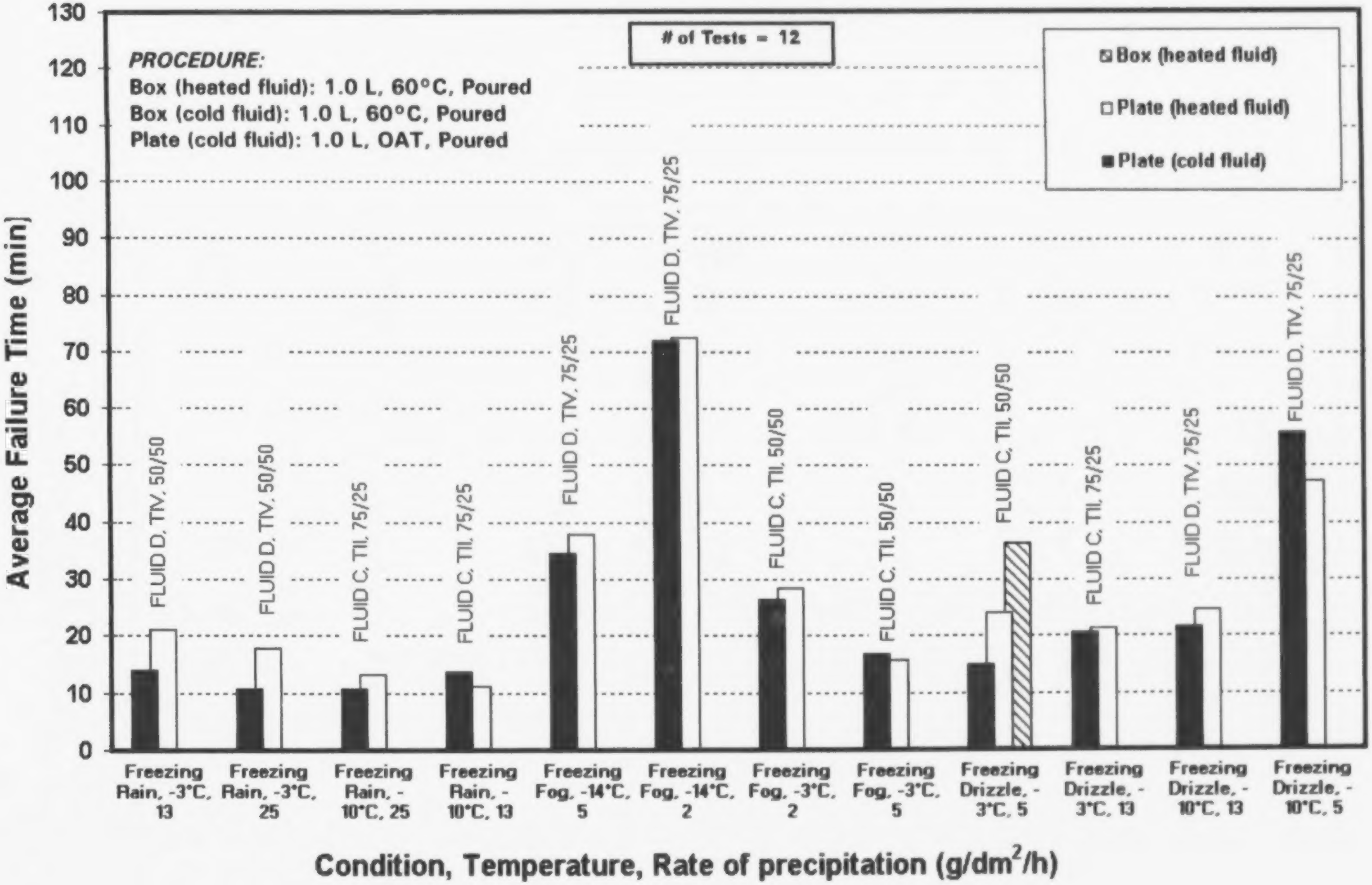
PROCEDURE:
Box (heated fluid): 1.0 L, 60°C, Poured
Box (cold fluid): 1.0 L, 60°C, Poured
Plate (cold fluid): 1.0 L, OAT, Poured

Figure 5.4: Comparison of Failure Times Between Cold Fluid and Heated Fluid on Plates for Diluted Type II and IV Fluids, Laboratory Tests

5.3 Observations

a) Endurance times for Type I and Type IV fluids showed a significant and consistent increase when tests were conducted outdoors in conditions of snow using the new Type I test protocol;

b) Laboratory tests conducted in December 2001 demonstrated improved endurance times in tests where heated fluid was applied to a box even though reduced fluid quantities were used;

c) Laboratory tests conducted in March 2002 showed very long endurance times in tests where heated fluid was applied to a box. These tests were mainly conducted at mild temperatures (-3°C). Simultaneous lab tests on Type I fluids using a box were unsuccessful because the box surface temperature failed to cool below 0°C; this was believed to be due to the latent heat effect. It was concluded that lab tests for Type I fluids should be based on the standard plate versus the box. Presumably the same effect influenced the test results for heated Type II and Type IV fluids in this set; and

d) Results from tests where 1.0 L of fluid was applied to plates at OAT and 1.0 L of fluid was applied at 60°C showed little difference in endurance times.

5.4 Summary of Results

The tests showed that the effect of heat did not reduce endurance times. In some cases, a significant improvement was observed.

Further investigation is recommended. It is important to gather information concerning the actual use of heated dilute fluids in one-step deicing operations (fluid temperatures and application quantities). Tests that reflect real operation parameters could then be designed.

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6. CONCLUSIONS

Following examination of several test surfaces and various procedures for fluid application, it was concluded that the empty 7.5 cm aluminum box, when treated with 0.5 L of fluid at 60°C, produced a reasonable representation of the rate of temperature decay demonstrated by wing leading edge surfaces in natural conditions. Tests using this newly developed Type I fluid protocol testing were conducted during the winter of 2001-02.

6.1 Use of Type I Protocol in Laboratory Conditions

The FAA expressed its desire to test the new protocol indoors, to determine whether the Type I protocol can be implemented indoors. A series of exploratory tests were conducted using an empty aluminum box test surface. As this test protocol did not prove satisfactory for indoor testing, it was decided to return to the original laboratory procedure for determining endurance times, based on the standard aluminum plate.

6.2 Influence of Latent Heat at Warm Temperatures

When examining the use of an empty aluminum box test surface for laboratory testing, it was observed that the release of latent heat of freezing caused the surface to warm and thus extended the interval until freezing occurred. One of the problems encountered in examining this phenomenon was the lack of understanding of how real aircraft wings respond in similar conditions. Do they also undergo an increase in temperature and thereby experience an extended endurance time? An exploration of wing temperature responses following deicing in freezing precipitation conditions could provide an answer as to how well the temperature profiles of empty aluminum box test surfaces correspond to wing temperature profiles during similar precipitation conditions. This type of study would also produce data that could prove useful to examine the validity of laboratory endurance times resulting from tests conducted at -3°C, including those tests using the conventional Type I procedure on flat plates. Similar tests should be conducted outdoors under freezing rain precipitation on the JetStar wing and using the artificial freezing rain sprayer.

6.3 Generation of Holdover Times Using the New Type I Fluid Test Protocol

Based on a parallel study involving a survey of winter weather data and deicing operations at several airports, the Type I fluid HOT table format was improved.

The changes to the table format included the elimination of the "above 0°C" row, the addition of a new temperature row (above -3°C) and the addition of a column for Light Snow. These changes are described in Transport Canada Report TP 13993E *Impact of Winter Weather on Holdover Time Table Format* (5).

During the winter of 2001-02, APS and AMIL conducted a combined total of 193 Type I endurance time tests in snow using the newly developed Type I protocol. Based on these tests, HOT tables were produced and presented to the industry at the SAE G-12 Holdover Time Subcommittee in Frankfurt in June 2002. The HOT values were found to be between the previous 6 to 15 minute values and the lower values adopted in May 2002. At these meetings, many industry members expressed their satisfaction with the quantity and quality of the data presented. The combined results from APS and AMIL cover a wide range of temperatures and precipitation rates; therefore, the data set can be applied to any temperature and precipitation rate that the regulators choose for snow.

The new Type I HOT table was generally accepted by the industry, with the exception of the lower precipitation rate limit for the new 'Light Snow' column. TC has decided that a lower limit of 3 $g/dm^2/h$ should be used, while the FAA has selected a lower limit of 5 $g/dm^2/h$.

To quantify the results obtained using the new protocol, APS conducted endurance time tests on empty aluminum boxes and on standard HOT flat plates. Fluid endurance time tests on standard plates using the traditional HOT procedure were conducted to provide a baseline for comparison. The endurance times obtained using the newly developed Type I protocol (on boxes) were on average 70 to 80 percent higher than those developed using the regular endurance time plate.

The Association of European Airlines (AEA) still has plans to use the HOT tables as presented at the industry meetings held in 2000 in Toulouse (holdover times based on tests conducted using regular ET plates and with fluid applied at 20°C).

6.3.1 Comparison of Previous Full-Scale Wing Tests with New Protocol Results

In previous winters, APS conducted full-scale tests on aircraft wings at several airports. Tests with each aircraft consisted of spraying the wing with heated Type I fluid and observing the contamination of the fluid while the wing gradually cooled, until complete wing failure.

The combined data set of the tests conducted on empty aluminum boxes by APS and AMIL was compared to the fluid failure data points obtained from full-scale tests. From the results, the full-scale tests were found to be a good representation of the newly conducted tests using the heated fluid on boxes.

6.4 Expansion of the HOT Table to Account for Fluid Concentration

A HOT table with cells that recognize/take into account the variability in fluid strength (standard premix 50/50 and 10°C FFP buffer) was considered. To address this, APS conducted 10°C buffer fluid tests and standard premix fluid tests simultaneously, so both test surfaces were subjected to the same outside air temperature, wind speed, and precipitation rate.

According to the endurance time test results, the standard mix fluid had, on average, an endurance time of about 10 percent longer than the 10°C buffer fluid. Based on these results, a HOT table having cells that recognize variability in fluid strength (50/50 premix and 10°C FFP buffer) for Type I fluids was not implemented.

6.5 Adherence of Type I Fluids at Mild Temperatures

In some cases during testing, it was observed that a short while after fluid failure, the contamination adhered to the test surface.

At milder temperatures (-3°C and above) the fluid often had been completely diluted to water sometime before freezing. Surface protection was provided solely by heat in these cases. When freezing finally occurred, the resulting ice was adhered to the surface. Prior to this, fluid endurance tests in snow conditions conducted on flat plates did not demonstrate adherence.

6.6 Application of Type I Protocol to Diluted Type II and Type IV Fluids

Industry members at an SAE G-12 meeting in November 2000 suggested that the endurance time test procedures for Type II and Type IV fluids, at 50/50 and 75/25 dilutions, should also recognize the contribution of heat and use the same test procedure as that for the Type I fluids. Preliminary tests were conducted and it was concluded that the effect of heat did not reduce endurance times. In some cases a significant improvement was observed.

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7

7. RECOMMENDATIONS

Based on the tests conducted, the following recommendations are made.

7.1 Use of Type I Protocol in Laboratory Conditions

As the test protocol using the heated empty aluminum box did not prove satisfactory for testing indoors, further investigation is not required at this time.

7.2 Influence of Latent Heat at Warm Temperatures

It is recommended that tests be conducted to examine whether latent heat of freezing influences Type I fluid endurance times for freezing rain and, to a lesser extent, drizzle on wings at mild temperatures in outdoor conditions. This examination should initially be conducted on empty aluminum boxes and on plates using an artificial rain sprayer positioned sufficiently high to ensure that the drops are cooled to ambient temperature. Tests should progress to the use of the JetStar wing as a test surface. The surface temperature and nature of freezing should be documented, and the results compared to those obtained in the laboratory on the same test surfaces.

7.3 Generation of Holdover Times Using the New Type I Fluid Test Protocol

Currently three Type I fluid HOT tables are being published by TC, the FAA, and AEA. The holdover times to be published by TC and the FAA are based on the tests conducted during the winter of 2001-02 by APS and AMIL, while AEA refers to holdover times based on tests conducted using regular ET plates and with fluid at 20°C.

Activities should be undertaken to assist TC, the FAA, and AEA in an attempt to harmonize the Type I fluid HOT tables.

7.4 Expansion of the HOT Table to Account for Fluid Concentration

While conducting the snow endurance tests using the new test procedure, it was observed that the cost effectiveness of applying Type I deicing fluid at full strength versus 10°C buffer is minimal. In many conditions, little or no additional endurance time is generated from the richer (and more expensive) fluid mix.

Because the analysis of test results indicated that there is no significant difference in the endurance time between the 10°C buffer fluid and standard mix fluid, no further investigation is suggested at this time.

7.5 Adherence of Type I Fluids at Mild Temperatures

For operations in wintertime conditions, TC and FAA regulations specify that aircraft must adhere to the clean wing principle, i.e. there must be no adhering contamination on critical aircraft surfaces at takeoff. Since contamination adherence is the critical aspect of the clean wing principle, it would be useful to have a better understanding of the relationship between fluid endurance time and the time that adherence occurs. The difference in those times may be considered a safety buffer and will vary considerably in different conditions.

Because adherence was observed during snow deicing tests with Type I fluid, it is recommended that tests be conducted to document the time at which adherence occurs relative to the time when fluid failure was noted (endurance time). A graphical display of the results should be developed showing adherence times versus endurance times for fluid types in different conditions. The interval between fluid failure and adherence should be examined to consider whether the formulation of holdover times should take into account instances of early adherence.

7.6 Application of Type I Protocol to Diluted Type II and Type IV Fluids

Tests exploring the influence of heat on endurance times when using dilute Type II and Type IV fluids in a one-step deicing procedure showed markedly longer endurance times.

It is recommended to further examine the suitability of using the new Type I outdoor test protocol to measure snow endurance times for heated Type II and Type IV fluids diluted to 75/25 and 50/50 concentrations in a one-step de/anti-icing procedure, as follows:

a) Collect information from operators using heated Type II or Type IV fluid to document the quantity and temperature at which the fluid is typically applied. Examine whether this results in a cooling profile similar to the generic wing profile used for Type I fluid; and

b) Examine whether the influence of heat on endurance times is brand-specific or whether a generic table may result.

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3. Chaput, M., Campbell, R, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13991E (to be published).

4. Dawson, P., Hanna, M., Chaput, M., Peters, A., Blais, N., *Aircraft Deicing Fluid Freeze Point Buffer Requirements for Deicing Only Conditions*, APS Aviation Inc., Transportation Development Centre, Montreal, November 1999, TP 13478E, 176.

5. Moc, N., Alwaid, A., *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13993E (to be published).

6. Hunt, M., Chaput, M., Dawson, P., Hanna, M., Peters, A., D'Avirro, J., *Characteristics of Failure of Aircraft Anti-Icing Fluids Subjected to Precipitation*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1999, TP 13484E (to be published).

7. D'Avirro, J., Peters, A., Hanna, M., Dawson, P., Chaput, M., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1996/97 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 1997 TP 13131E, 232.

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A

APPENDIX A

TERMS OF REFERENCE – PROJECT DESCRIPTION EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT

EXCERPT FROM
TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT – DC 202
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING
WINTER OPERATIONS CONTAMINATED AIRCRAFT – GROUND
2001-2003
(March 2002)

5.5 Development of Protocol for Type I Testing

5.5.1 Report on results from field tests comparing the endurance times generated by the new outdoor test procedure to those observed on aircraft leading edges in natural snow conditions;

5.5.2 Support industry activities leading to new test standard for Type I fluids;

5.5.3 Examine results obtained from FAA tests with American Eagle to study the duration of holdover times actually used in live operations and the incidence of returns for an additional de-icing to understand whether they support published holdover times;

5.5.4 Finalize any exceptions determined during Type I fluid endurance time tests in outdoor and indoor test conditions using new protocols;

5.5.5 Evaluate the results of tests, examining whether the new indoor and outdoor test procedures are suitable for testing 75/25 and 50/50 concentrations of Type II and IV fluids used in a one-step de-icing/anti-icing operation; and

5.5.6 Make recommendations to industry and finalize endurance tests with new protocol.

5.7 Expansion of Type I Fluid HOT Guideline Table

5.7.1 Conduct a feasibility study to identify the utility and potential outcome of producing a Type I HOT table that reflects:

a) fluid at full strength (50 / 50) fluid as well as fluid at a 10°C buffer;

b) fluid temperature reflecting both the current 60°C and field operations with fluid temperatures lower than 60°C at the spray nozzle;

c) an additional precipitation rates at a lower value such as 5 g/dm^2/hr; and

d) additional temperature breaks at milder temperatures such as -3°C.

5.7.2 Prepare a test procedure to examine the impact on endurance times of those parameters that the feasibility study found to have potential value;

5.7.3 Conduct tests;

5.7.4 Analyze results;

5.7.5 Recommend modified test procedures; and

5.7.6 Prepare material to support proposing and gaining acceptance of a new HOT guideline format.

B

APPENDIX B

PROCEDURE FOR EXAMINATION OF FLUID QUANTITIES FOR SAE TYPE I FLUID ENDURANCE LABORATORY TEST

CM1680

EXAMINATION OF FLUID QUANTITIES FOR SAE TYPE I FLUID ENDURANCE LABORATORY TEST PROCEDURE

Winter 2001-2002

Prepared for

Transportation Development Centre
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by: Peter Dawson

Reviewed by: John D'Avirro

APS AVIATION INC.

7 September 2001
Version 1.0

Development of Type I Protocol

EXAMINATION OF FLUID QUANTITIES FOR SAE TYPE I FLUID ENDURANCE LABORATORY TEST PROCEDURE

1. OBJECTIVES

The temperature decay rate profile resulting from applying SAE Type I fluid to the test surface must match the documented generic profile for the wing leading edge in outdoor conditions. The controllable factors (other than fluid temperature) that govern the decay rate are:

- quantity of fluid
- type of surface, and
- rate of fluid application.

The FAA has requested that APS examine the use of fluid heated to 60°C in the laboratory test method. The objective of this test procedure is to examine the controllable factors to identify values suitable for tests conducted in the laboratory, when the fluid is heated to 60°C.

These tests will be scheduled on September 13, 2001 at the Climatic Engineering Facility (CEF) of the National Research Council Canada (NRC) at Ottawa.

2. PROCEDURE (SET-UP)

1. Set up an EXCEL file on the laptop computer containing the existing graphs and supporting data for the generic wing leading edge temperature profile and the temperature profile for tests conducted indoors on flat plates;
2. Clean surfaces in preparation for testing. Prepare one thin plate with insulated backing;
3. Mount 2 thermistors on each surface at the 15 cm (6″) line and confirm operation;
4. Ensure loggers are functional and labelled; clear loggers and reset to sample at 8-second intervals;
5. Set-up E-Mail on laptop for data transmission;
6. Prepare mix of Type I fluid (20 L) to a fluid freeze point of −20°C or low enough to prevent freezing on the surfaces;

7. Heat fluids to designated temperatures for testing;
8. Synchronize computer and clocks with Environment Canada time;
9. Install test surfaces on stand; and
10. Install Vaisala probe at test stand.

3. PROCEDURE (TEST)

1. Apply fluid at designated temperature, quantity and application method on each surface. Warm spreaders prior to each test by pouring water heated to the temperature of the fluid mix to be tested (either 20°C or 60°C) into the spreader and letting it drain just prior to test. As only one fluid mix is used in these tests, tests can be run in rapid succession on consecutive plates using the same spreader and fluid temperature, to avoid the need to reheat the spreader;
2. Monitor temperatures (8 seconds logging) until temperature decays to within 10% of original value (OAT);
3. Record ambient temperature at stand location from Vaisala meter;
4. Following each test set or as needed, develop graph in EXCEL showing temperature decay rate profiles for various test conditions. Include generic wing profile (adjusted to lab temperature) as reference; and
5. Compare profiles from test runs. Decide approach for additional tests based on judgement as to what combination of fluid quantity, plate thickness and spreader application rate will cause the test surface temperature profile to reflect the generic wing profile.

4. EQUIPMENT

See Attachment B-1.

5. DATA FORMS

Fill in line on test plan related to each test.

6. PERSONNEL

Two people required.

ATTACHMENT B-1
EQUIPMENT LIST

Stand	
3 standard plates (3.2 mm)	
2 thin plates (1.6 mm)	
1 thin plate (1.6 mm) with insulated backing	
Spare insulation and glue	
Thermistor kit	
At least 15 thermistors	
Software	
Laptop	
Loggers	
Acetone	
Spreaders used for Type I protocol tests	
Tape for adjusting number of holes	
Type I fluid mix (20 L)	
Microwave	
Measuring containers	
Thermos containers (6)	
Heat gun	
Aluminum speed tape	
Temperature probe (Wahl)	
Scotchbrite to prepare plates	
Vaisala meter	
Hot plate and pots	

Table B-1
Test Plan

Set	Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Spreader Rate	Start time	Ambient Temp (°C)	Comments
1	1	Std plate (3.2 mm)	20	1.0	Pour			
1	2	Std plate (3.2 mm)	20	1.0	Pour			Duplicate of run 1
1	3	Std plate (3.2 mm)	20	1.0	½ holes			
1	4	Std plate (3.2 mm)	20	1.0	½ holes			Duplicate of run 3
2	5	Std plate (3.2 mm)	60	0.5	½ holes			
2	6	Thin plate (1.6 mm)	60	0.5	½ holes			
2	7	Thin plate (1.6 mm)	60	0.5	1/4 holes			
2	8	Thin plate (1.6 mm) Insulated	60	0.5	½ holes			
2	9	Thin plate (1.6 mm) Insulated	60	0.5	1/4 holes			
3	10	Std plate (3.2 mm)	60	0.25	½ holes			
3	11	Thin plate (1.6 mm)	60	0.25	½ holes			
3	12	Thin plate (1.6 mm)	60	0.25	1/4 holes			
3	13	Thin plate (1.6 mm) Insulated	60	0.5	½ holes			
3	14	Thin plate (1.6 mm) Insulated	60	0.5	1/4 holes			

Note1: Some tests will be duplicated if they show promising results.

Note2: The base case for spreader rate is ½ of the drain holes operational to conform to the rate selected for the outdoor test procedure

C

APPENDIX C

INTERIM REPORT FOR EXAMINATION OF FLUID QUANTITIES FOR LABORATORY TRIALS OF SAE TYPE I FLUID ENDURANCE

CM1680

INTERIM REPORT
EXAMINATION OF FLUID QUANTITIES FOR LABORATORY TRIALS OF SAE TYPE I FLUID ENDURANCE
Winter 2001-2002

Prepared for

Transportation Development Centre
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by: Peter Dawson

APS AVIATION INC.

16 October 2001
Version 1.0

Development of Type I Protocol

EXAMINATION OF FLUID QUANTITIES FOR LABORATORY TRIALS OF SAE TYPE I FLUID ENDURANCE

1. BACKGROUND AND OBJECTIVE

The report on examination of a protocol for Type I fluid testing concluded that the temperature profile produced by the current Type I test procedure on the standard flat plate in calm laboratory conditions provided a sufficiently accurate representation of the temperature decay rate demonstrated by wings in natural outdoor conditions. The recommendation specified a fluid quantity of 1.0 L at 20°C (with a range +2°C and -0°C).

It was further recommended that the method of applying fluid should be modified to use the spreader as described for outdoor trials.

The FAA has requested supplementary tests to examine the use of fluid heated to 60°C in the laboratory test method. The objective of this is to identify required values of other test parameters when the fluid is heated to 60°C. Test parameters (other than fluid temperature) that govern the rate of temperature decay of the test surface are:

- quantity of fluid
- type of surface, and
- rate of fluid application.

The goal is to have a laboratory test procedure that generates a temperature decay rate profile resulting from applying SAE Type I fluid to the test surface that closely matches the documented generic profile for the wing leading edge in outdoor conditions.

Tests were conducted on September 13, 2001 at the Climatic Engineering Facility (CEF) of the National Research Council Canada (NRC) at Ottawa.

2. PROCEDURE AND RECORD OF TESTS CONDUCTED

The test procedure followed was as described in the test procedure document, dated 7 September 2001. These tests were run in conjunction with a series of tests for which the laboratory had already been booked.

In the Type I protocol study, examination of the rate of fluid application led to a recommended rate of fluid delivery as produced by modifying the existing Type I spreader. The modification consisted of simply taping over ½ of the drain holes to slow down the rate of draining. The modified spreader was the base case spreader used in the 13 Sep 2001 tests being discussed. These tests also examined a further reduction of application rate where only ¼ of the spreader holes were active.

In addition to conducting the tests shown in the procedure, other tests were conducted to investigate the affect of further modifying test parameters.

The matrix of tests conducted is shown in Table C-1.

3. RESULTS

Examination of the results led to the following conclusions:

3.1 Application on standard plate: 1.0 L at 20°C poured (traditional HOT method)

a) Results from this procedure continued to produce temperature profiles below but within 2 standard deviations of the generic wing mean (see Figure C-7). Results from this session (runs 1 & 2) were slightly cooler than in previous tests (see Figure C-1).

3.2 Comparison of 1.0 L at 20°C with spreader versus poured

a) Applying fluid with the spreader (runs 3 & 4 in Figure C-7) produced a profile positioned between the curve resulting from pouring and the mean temperature curve of the generic wing; and

b) To produce an exact match to the generic wing, it is estimated that a 5°C increase in fluid temperature (1.0 L at 25°C with spreader) would be required. Alternatively, a small decrease to the spreader rate of delivery might suffice. There was not enough time available at the laboratory ambient temperature of 10°C to test these options.

3.3 Results from thinner test surface

A thinner test surface (1.6 mm thick versus the standard plate thickness of 3.2 mm) was tested. A further variation to this incorporated a layer of insulation on the bottom side of the plate, to slow the rate of cooling. The fluid quantity was varied (0.5 and 0.25 L) and the spreader application rate was varied.

a) The main conclusion is that the thin plate did not produce the desired temperature profile regardless of the variations in fluid application. The initial temperature was too high, and the cooling rate too rapid. Figures C-2, C-3 and C-4 display the results from some of these tests; and

b) It is interesting to note that the increasing the fluid quantity from 0.25 L (Figure C-3) to 0.5L (Figure C-2) at a fixed application rate did not generate any improvement in profile. However, slowing the application rate (from 1/2 to 1/4 of the holes active) for a fixed quantity did result in a higher profile.

Table C-1
Tests Conducted 13 Sep 2001

Set	Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Spreader Rate	Start Time	Ambient Temp (°C)	Comments
1	1	Std plate (3.2 mm)	20	1.0	Pour			
1	2	Std plate (3.2 mm)	20	1.0	Pour			Duplicate of run 1
1	3	Std plate (3.2 mm)	20	1.0	½ holes			
1	4	Std plate (3.2 mm)	20	1.0	½ holes			Duplicate of run 3
2	5	Std plate (3.2 mm)	60	0.5	½ holes			
2	6	Thin plate (1.6 mm)	60	0.5	½ holes			
2	7	Thin plate (1.6 mm)	60	0.5	1/4 holes			
2	8	Thin plate (1.6 mm) Insulated	60	0.5	½ holes			
2	9	Thin plate (1.6 mm) Insulated	60	0.5	1/4 holes			
3	10	Std plate (3.2 mm)	60	0.25	½ holes			Link to run 17
3	11	Thin plate (1.6 mm)	60	0.25	½ holes			
3	12	Thin plate (1.6 mm)	60	0.25	1/4 holes			
3	13	Thin plate (1.6 mm) Insulated	60	0.5	½ holes			
3	14	Thin plate (1.6 mm) Insulated	60	0.25	1/4 holes			

Note: The base case for spreader rate is ½ of the drain holes operational to conform to the rate selected for the outdoor test procedure.

Table C-1 *(continued)*
Tests Conducted 13 Sep 2001

Set	Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Spreader Rate	Start Time	Ambient Temp (°C)	Comments
	15	Std plate (3.2 mm)	60	1.0	Pour			
	16	Thin plate (1.6 mm) Insulated	60	0.25	½ holes			
	17	Std plate (3.2 mm)	60	0.25	¼ holes			Link to run 10
	18	Std plate (3.2 mm)	60	0.35	½ holes			
	19	Std plate (3.2 mm)	60	0.35	¼ holes			
	20	Std plate (3.2 mm)	60	0.25	½ holes			Duplicate of 10
	21	Std plate (3.2 mm)	60	0.25	¼ holes			Duplicate of 17
	22	Std plate (3.2 mm)	60	0.35	½ holes			Duplicate of 18

Note: The base case for spreader rate is ½ of the drain holes operational to conform to the rate selected for the outdoor test procedure.

3.4 Application of fluid at 60°C versus 20°C on the standard plate

a) In Figure C-5, the temperature profile from applying 0.5 L of fluid at 60°C with the spreader lies far above the mean profile produced by the traditional HOT application of 1.0 L at 20°C;

b) The temperature profile from applying 1.0 L of fluid at 60°C by pouring is equivalent to the temperature profile from applying 0.5 L of fluid at 60°C with the spreader; and

c) Applying 1.0 L at 20°C with the spreader generates a profile just above the mean profile produced by the traditional HOT application of 1.0 L at 20°C by pouring.

3.5 Application of reduced amounts of fluid at 60°C on the standard plate

a) In Figure C-6, the application of 0.5 L of fluid at 60°C with the spreader (discussed in 4a) produces a profile in the upper half of the distribution describing the mean generic wing;

b) Reducing the fluid amount to 0.35 and 0.25 L generates lower profiles;

c) Of this set of tests with the fluid at 60°C, the closest match to the generic wing is provided by 0.25 L applied with the reference spreader; and

d) Generally, curves resulting from application of fluid at 60°C are not satisfactory matches to the generic wing curve.

3.6 Summary chart (Figures C-7, C-7a and C-7b)

Figure C-7 gives results from certain tests that were duplicated to improve confidence in results. These tests were all run on the standard test plate. The information on this figure is separated for better viewing as follows:

a) Figure C-7a shows results of attempts to match the wing mean curve by varying fluid quantities and application rates with a fluid temperature of 60°C.; and

b) Figure C-7b shows results of attempts to match the wing mean curve by changing fluid temperature to 20°C and varying the application rate, while keeping the fluid quantity at 1.0 L.

4. CONCLUSIONS

Attempts to generate a temperature decay rate in the laboratory that exactly matches the generic wing mean temperature decay rate were not entirely successful.

1. Use of thin plates did not produce the desired temperature profile regardless of the variations in fluid application. The initial temperature was too high, and the cooling rate too rapid.

2. Staying with the standard thickness plate, but varying fluid quantities and application rates with a fluid temperature at 60°C, did not produce the right shape of curve (Figure C-7a).

3. Staying with the standard thickness plate, keeping the fluid quantity at 1.0 L, but applying the fluid with a spreader versus pouring, generates a temperature curve that better matches the wing curve (Figure C-7b). Applying 1.0 L at 60°C generates a curve well above the wing curve (Figure C-7b).

4. For laboratory tests to evaluate Type I fluid endurance times, the best

solution to date is the proposed procedure that specifies 1.0 L of fluid at 20°C, applied with the spreader.

5. This might be further refined to produce a closer match to the generic wing through either of two approaches:

    a) It is estimated that a 5°C increase in fluid temperature (1.0 L at 25°C with spreader) would give a closer match.

    b) Alternatively, a small decrease to the spreader rate of delivery might suffice.

There was not enough time available at a constant laboratory ambient temperature to test these options.

FIGURE C-1

Standard Plate Temperature Profiles versus HOT Plate Mean Curve

1.0 L @ 20°C, Poured and Spreader, Normalized to OAT -9°C

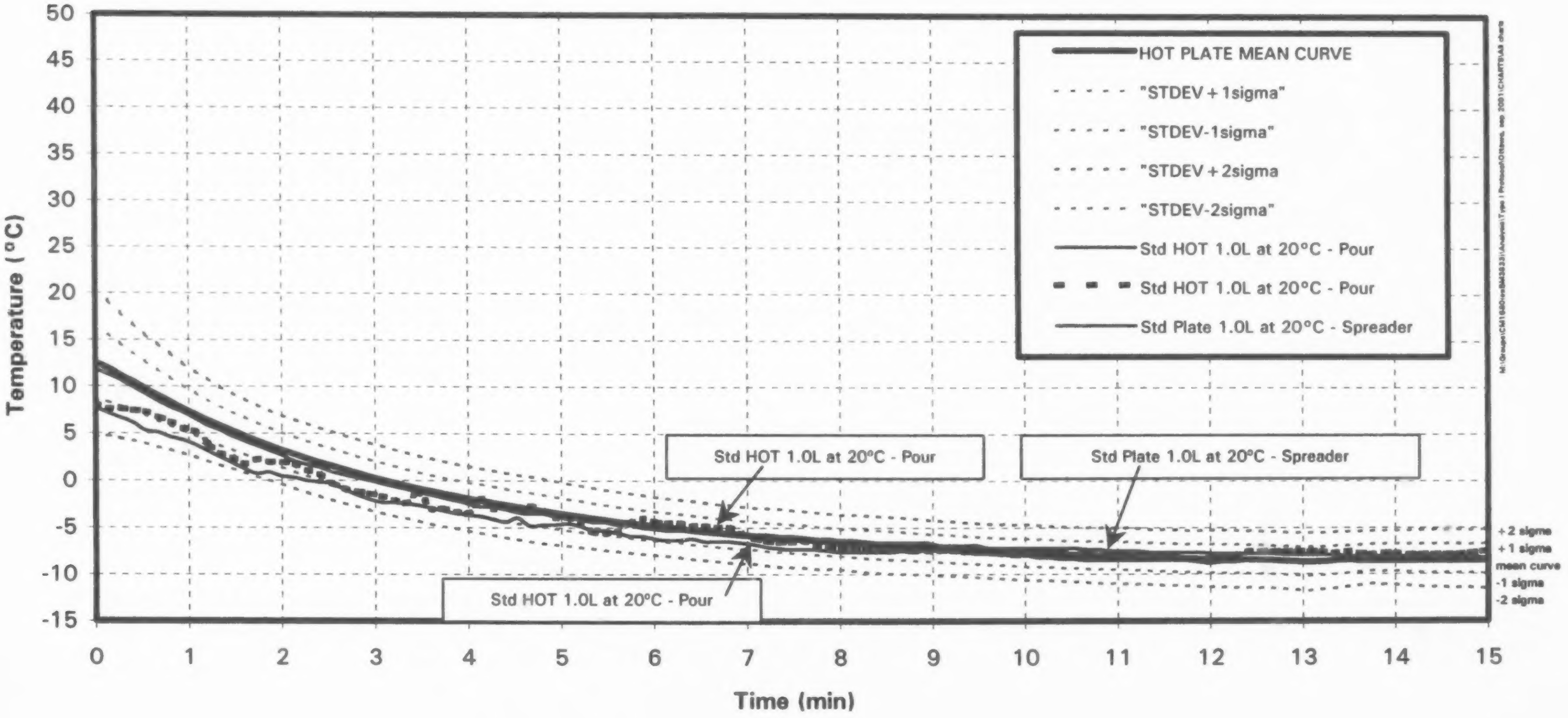


FIGURE C-2

Thin Plate Temp. Profiles versus Generic Wing Leading Edge Profile
0.5 L at 60°C, Spreader

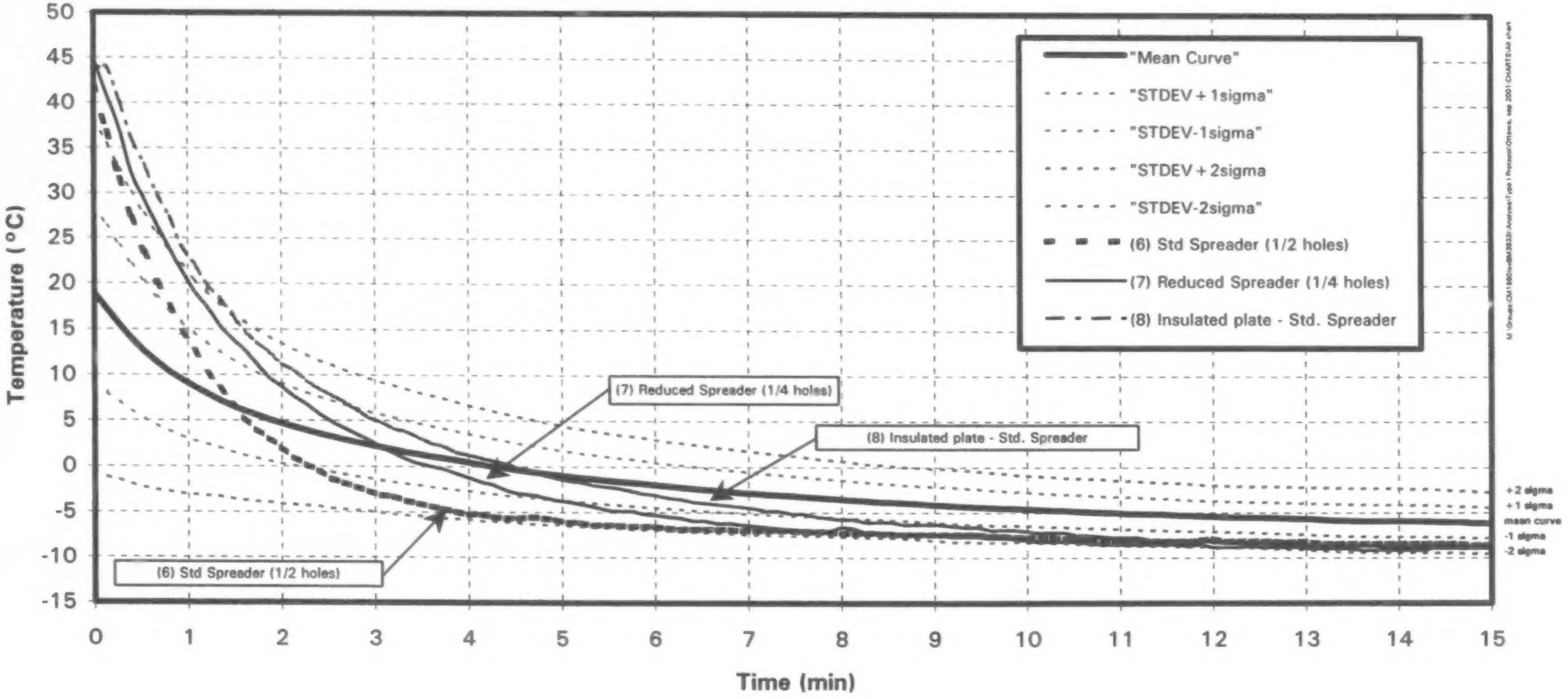


FIGURE C-3
Thin Plate Temperature Profiles versus Generic Wing LE Profile
0.25 L at 60°C, Spreader

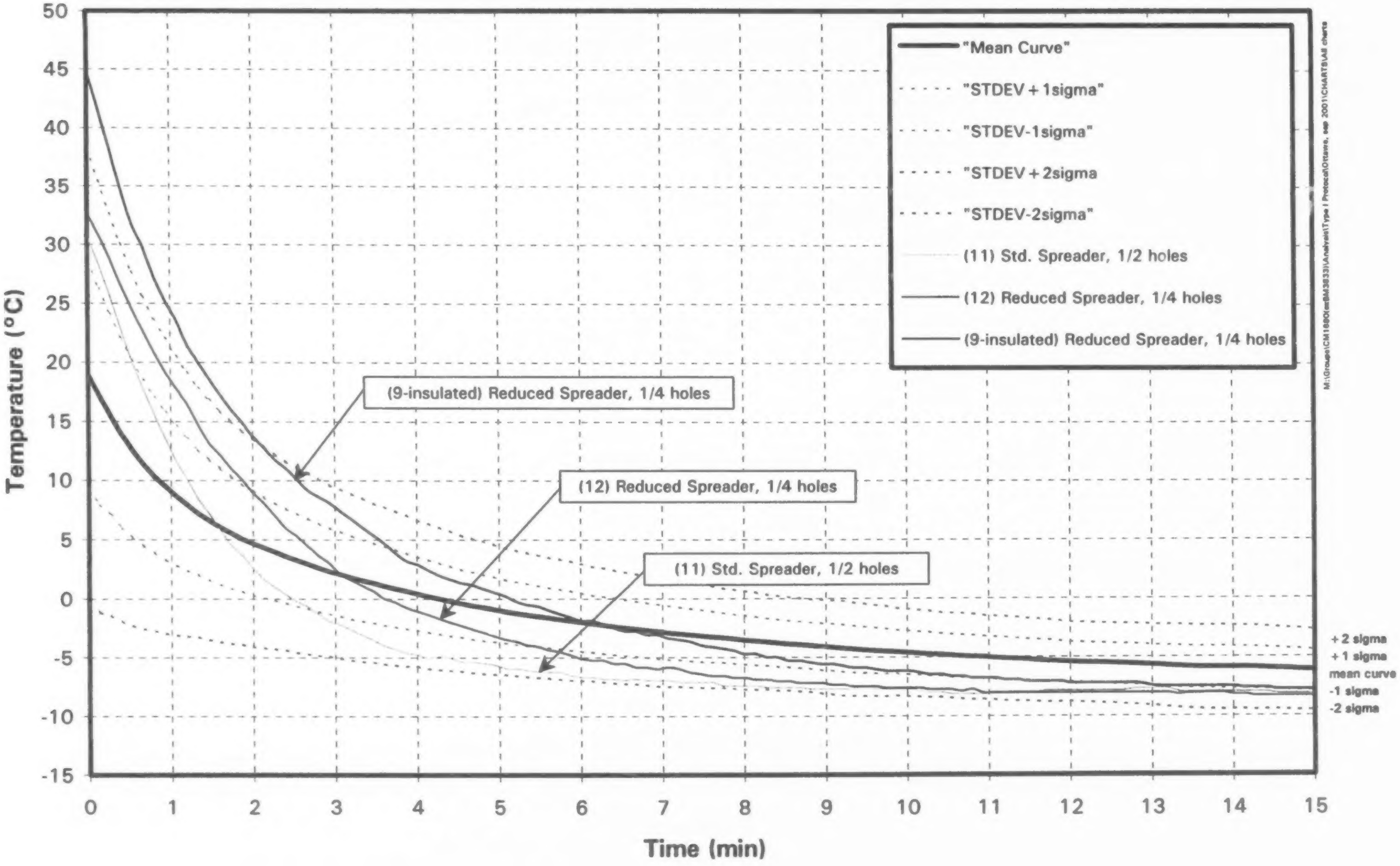


FIGURE C-4

Insulated Thin Plate Temperature Profiles versus Generic Wing LE Profile 0.5 L and 0.25 L at 60°C, Spreader

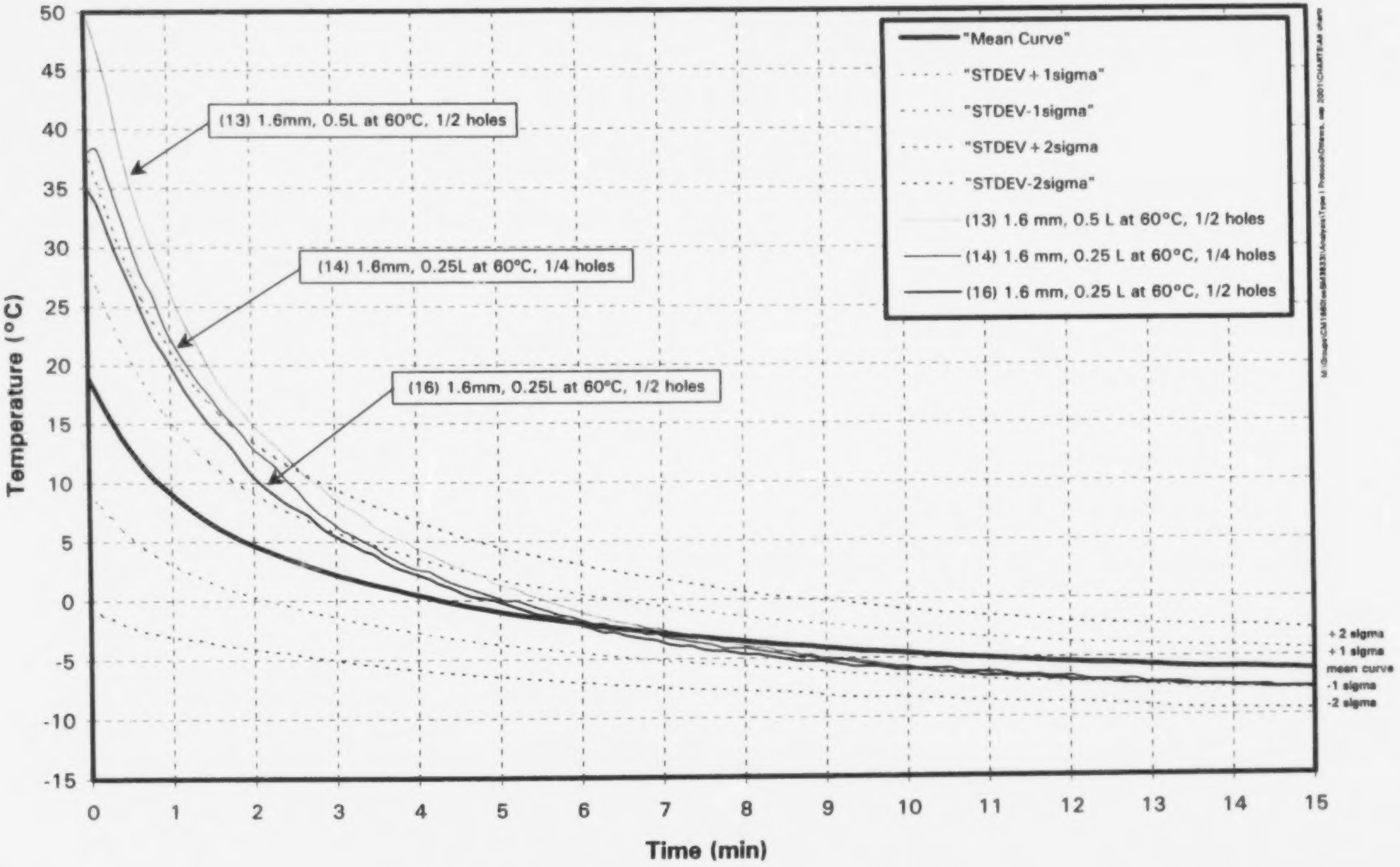


FIGURE C-5

Standard Plate Temperature Profile with fluid at 20°C and 60°C

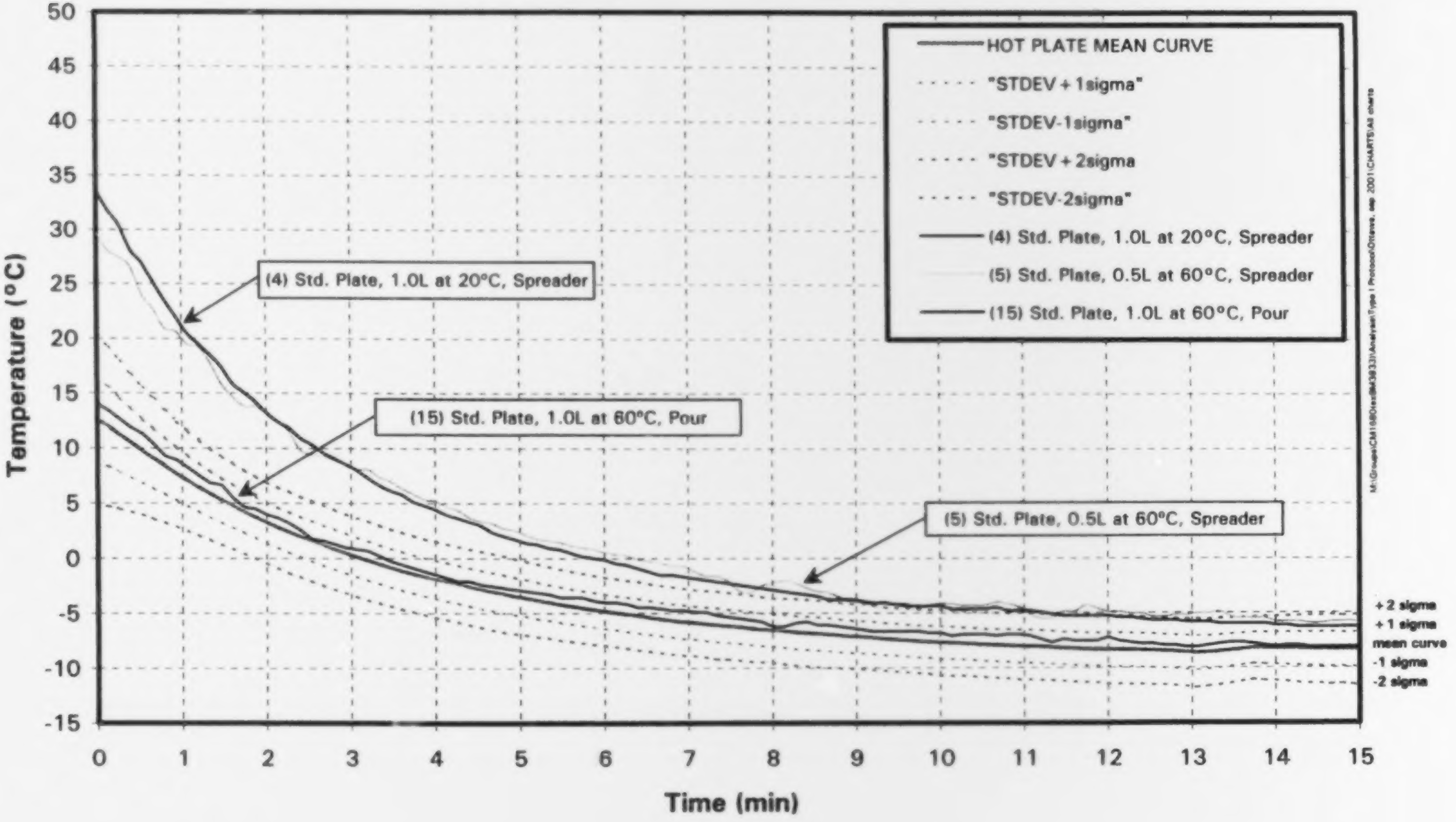


FIGURE C-6

Standard Plate Temperature Profiles with Various Applications versus Generic Wing LE Profile

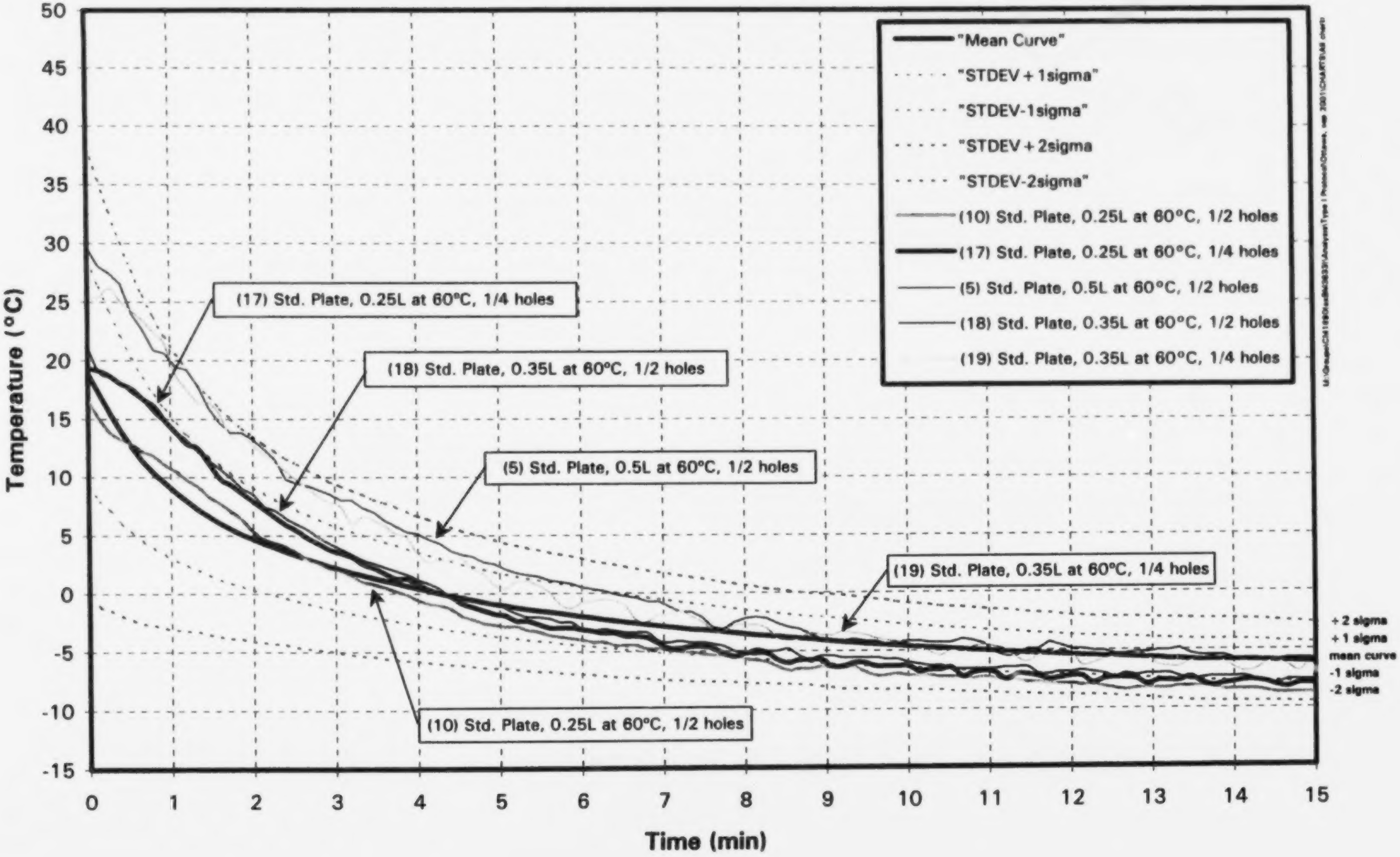


FIGURE C-7

Summary Comparison of Fluid Quantity, Temperature and Application Method versus Generic Wing LE Profile

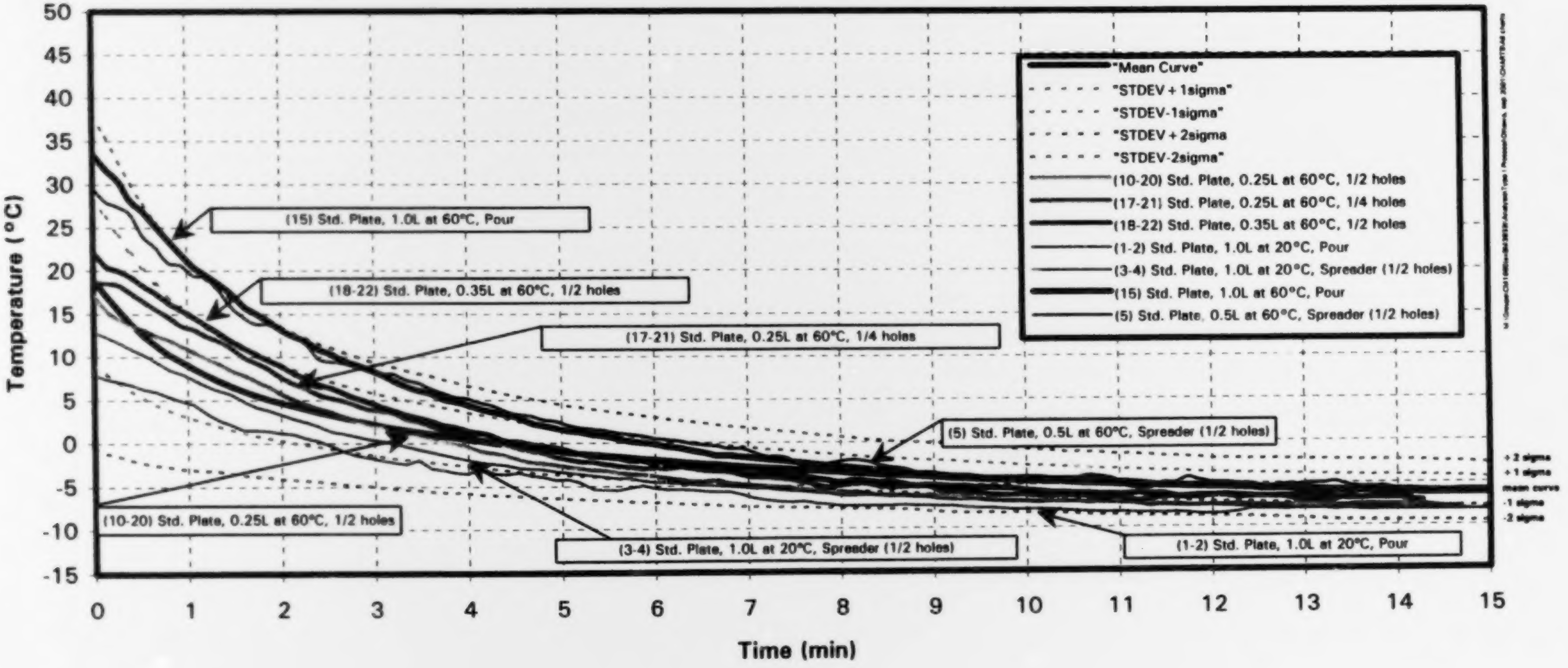


FIGURE C-7(a)
Summary Comparison of Fluid Quantity, Temperature and Application Method versus Generic Wing LE Profile

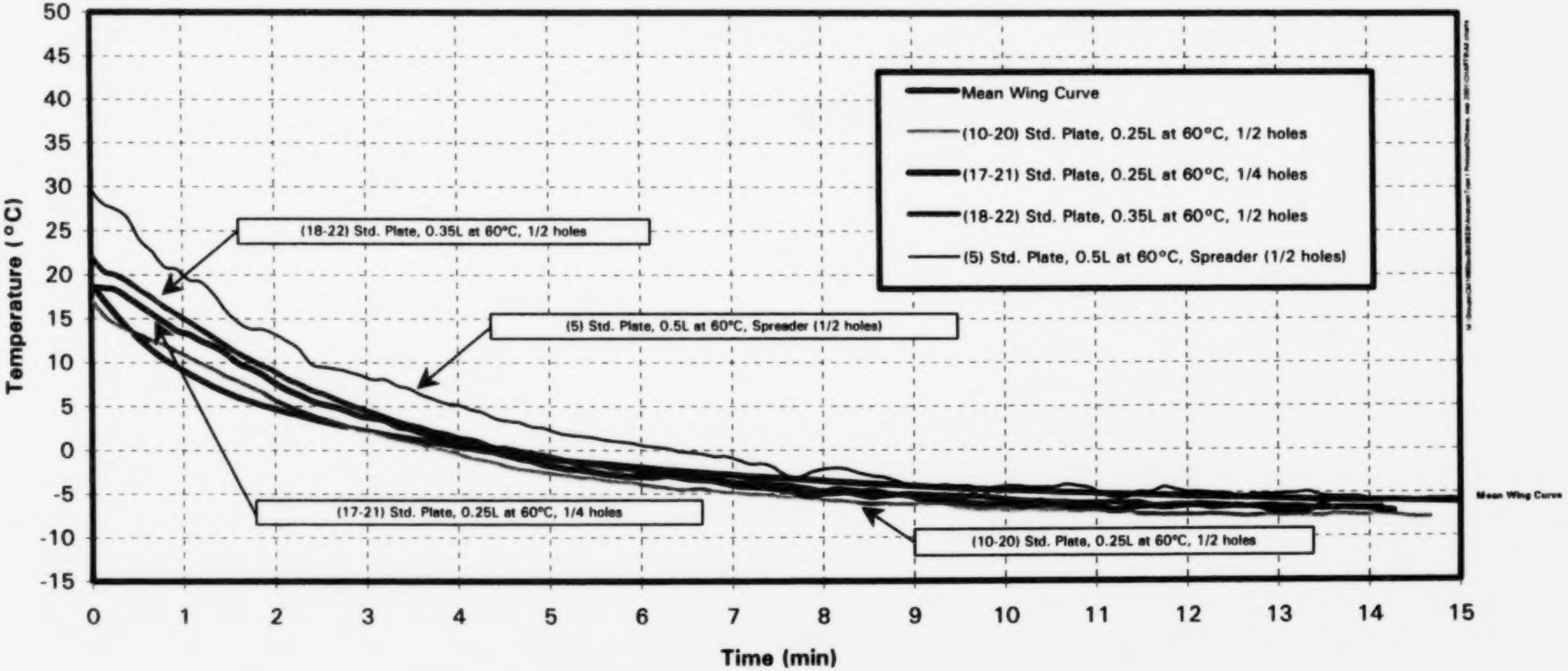
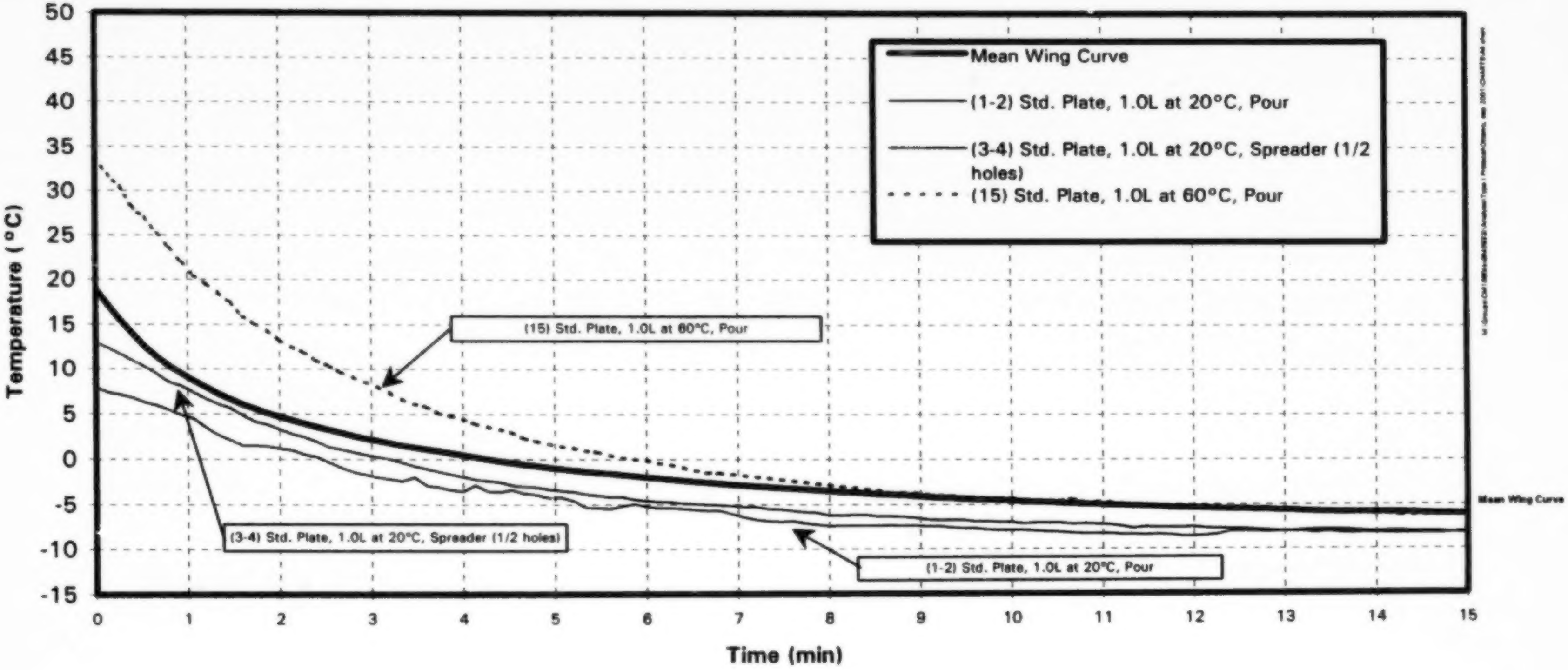


FIGURE C-7(b)
Summary Comparison of Fluid Quantity, Temperature and Application Method versus Generic Wing LE Profile



D

APPENDIX D

DETERMINATION OF LABORATORY TEST PARAMETERS USING AN EMPTY ALUMINUM BOX

- PROCEDURE
- RESULTS

CM1680

EXAMINE USE OF 60°C FLUID AND A COLD-SOAK BOX AS TEST SURFACE FOR SAE TYPE I FLUID ENDURANCE LABORATORY TESTS

Winter 2001-2002

Prepared for

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APS AVIATION INC. APS

22 November 2001
Version 1.0

Editorial Revision
15 November 2002
Version 1.1

Development of Type I Protocol

EXAMINATION OF FLUID QUANTITIES FOR SAE TYPE I FLUID ENDURANCE LABORATORY TEST PROCEDURE

1. OBJECTIVES

The temperature decay rate profile resulting from applying SAE Type I fluid to the test surface must match the documented generic profile for the wing leading edge in outdoor conditions. The factors that govern the decay rate are:

- fluid temperature
- quantity of fluid
- rate of fluid application
- exposure to wind, and
- type of surface.

Previous tests determined that the type I test procedure using one litre of fluid at 20°C applied to a flat plate in no-wind laboratory conditions produced a temperature profile that closely resembled the profile for the wing leading edge in outdoor conditions with natural wind.

The FAA has requested that APS examine the use of fluid heated to 60°C together with a cold-soak box as a test surface, for the laboratory test method. The objective of this test procedure is to identify what can be done to cause this combination to produce a temperature profile that matches the profile for the wing leading edge in outdoor conditions with natural wind.

These tests will be scheduled for the week of December 03 to 07, 2001 at the PMG Climatic Engineering Facility at Blainville, Quebec.

2. PROCEDURE (SET-UP)

1. Set up an EXCEL file on the laptop computer containing the existing graphs and supporting data for the generic wing leading edge temperature profile and the temperature profile for tests conducted indoors on flat plates;
2. Prepare test surfaces shown in equipment list.
3. Mount 2 thermistors on each surface at the 15 cm (6") line and confirm operation;
4. Mount a thermistor exposed to the air, at the stand;

5. Ensure loggers are functional and labelled; clear loggers and reset to sample at 8-second intervals;
6. Cool chamber to -10°C. All testing will be conducted at this temperature;
7. Cool sufficient fluid to -10°C for pouring into box cavities;
8. Prepare mix of Type I fluid (20 L) to a fluid freeze point of -20°C or low enough to prevent freezing on the surfaces;
9. Heat fluid to 20°C and 60°C for testing;
10. Synchronize computer and clocks with atomic clock time;
11. Install test surfaces on stand;
12. Measure fluid delivery rate of small handheld sprayer; and
13. Set up air blower and ducting, measure temperature of air delivered to box cavity.

3. PROCEDURE (TEST)

1. Apply fluid at designated temperature, quantity and application method on each surface. Warm spreaders prior to each test by pouring water heated to the temperature of the fluid mix to be tested (either 20°C or 60°C) into the spreader and letting it drain just prior to test. As only one fluid mix is used in these tests, tests can be run in rapid succession on consecutive plates using the same spreader and fluid temperature, to avoid the need to reheat the spreader;
2. Monitor temperatures (8 seconds logging interval) until temperature decays to within 10% of original value (OAT);
3. Record ambient temperature at stand location using thermistor probe;
4. Following each test set or as needed, develop graph in EXCEL showing temperature decay rate profiles for various test conditions. Include generic wing profile (adjusted to lab temperature) as reference; and
5. Compare profiles from test runs. Decide approach for additional tests based on judgement as to what combination of fluid quantity, application rate and other factors will cause the test surface temperature profile to reflect the generic wing profile.

4. EQUIPMENT

See Attachment D-1.

5. DATA FORMS

Fill in line on test plan related to each test. See Table D-1 and Table D-2.

6. PERSONNEL

Four people required:

- One for continuous spreadsheet analysis;
- Two for test preparation and conduct;
- One to manage the test process and decide direction of further testing.

ATTACHMENT D-1
EQUIPMENT LIST

Stand	
2 standard plates (3.2 mm)	
3 cold-soak boxes with insulation	
2 cold-soak boxes without insulation	
1 cold-soak box without insulation, with apertures for blowing air through cavity	
1 cold-soak box, with thick (4.8 mm) surface	
Fluid for box cavity	
Brixometer	
Spare insulation and glue	
Thermistor kit	
At least 16 thermistors	
Software	
Laptop X 2	
Colour printer	
Loggers	
Ether	
Spreaders used for Type I protocol tests: 1/2 holes X 2 double number of holes X 2	
Tape for adjusting number of holes	
Sprayer for small fluid quantity (0.25 & 0.5 L) and any pressure tubing needed.	
Type I fluid mix (40 L)	
Microwave for heating fluid	
Measuring containers	
Thermos containers (6)	
Heat gun	
Aluminum speed tape	
Temperature probe (Wahl)	
Scotchbrite to prepare plates	
Hot plate and pots	
Air blower – cold air	
Air ducting to deliver air to box cavity	
Catch tray for fluids at PMG	
Wet dry vacuum	
Plastic tarps	
Fluid waste containers	
Tables for heating equipment	
Wipers	

Table D-1
Test Plan

Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Application type	Ambient Temp (°C)	Start time	Comments
1	Std plate (3.2 mm)	20	1.0	Std Pour (1/3 – 2/3)	-10		Reference base
2	Plate (3.2 mm)	20	1.0	Spreader, ½ holes	-10		
3	Plate (3.2 mm)	20	1.0	Spreader, 1/4 holes	-10		
4	Plate (3.2 mm)	20	1.0	Spreader, 1/4 holes	-10		
5	Plate (3.2 mm)	60	0.5	Spreader, ½ holes	-10		Plate vs box comparison
6	7.5 cm Insulated Cold-soak Box	60	0.5	Spreader, ½ holes	-10		
7	7.5 cm Insulated Cold-soak Box	60	0.25	Spreader, ½ holes	-10		Start with std box and 0.25L Vary application rate
8	7.5 cm Insulated Cold-soak Box	60	0.25	Spreader, all holes	-10		
9	7.5 cm Insulated Cold-soak Box	60	0.25	Spreader, double holes	-10		
10	7.5 cm Insulated Cold-soak Box	60	0.35	Spreader, ½ holes	-10		Vary fluid quantity for any promising outcomes from above
11	7.5 cm Insulated Cold-soak Box	60	0.35	Spreader, all holes	-10		
12	7.5 cm Insulated Cold-soak Box	60	0.35	Spreader, double holes	-10		
13	Cold-soak Box, no insulation	60	0.25	Spreader, all holes	-10		Examine effect of no insulation

Table D-1
Test Plan

Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Application type	Ambient Temp (°C)	Start Time	Comments
14	Cold-soak Box, no insulation	60	0.35	Spreader, all holes	-10		
15	Cold-soak Box, no insulation	60	0.25	Spreader, double holes	-10		Examine effect of no insulation along with faster rate
16	Cold-soak Box, no insulation	60	0.35	Spreader, double holes	-10		
17	Cold-soak Box, no insulation	60	0.1	Sprayed	-10		Examine effect of applying fluid by spraying
18	Cold-soak Box, no insulation	60	0.25	Sprayed	-10		
19	Cold-soak Box, no insulation	60	0.35	Sprayed	-10		
20	Box, no insulation	60	0.5	Sprayed	-10		
21	Cold-soak Box, 4.8 mm thick surface,	60	0.5	Spreader, 1/2 holes	-10		Examine effect of thicker surface along with varied fluid quantity and application rates
22	Cold-soak Box, 4.8 mm thick surface,	60	0.5	Spreader, 1/4 holes	-10		
23	Cold-soak Box, thick surface,	60	0.75	Spreader, 1/2 holes	-10		

Table D-1
Test Plan

Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Application type	Ambient Temp (°C)	Start Time	Comments
24	Cold-soak Box, no insulation, 50% filled with -10°C fluid	60	0.25	Spreader, 1/2 holes	-10		Examine effect of no insulation along with cold fluid in cavity
25	Cold-soak Box, no insulation, 50% filled with -10°C fluid	60	0.35	Spreader, 1/2 holes	-10		
26	Cold-soak Box, thick surface, 100% filled with -10°C fluid	60	0.25	Spreader, 1/2 holes	-10		Examine effect of filling cavity with cold fluid along with thicker surface
27	Cold-soak Box, thick surface, 100% filled with -10°C fluid	60	0.5	Spreader, 1/2 holes	-10		
28	Cold-soak Box, no insulation, with apertures for blowing cold air through cavity	60	0.25	Spreader, 1/2 holes	-10		Examine effect of no insulation along with air blown through cavity
29	Cold-soak Box, no insulation, with apertures for blowing cold air through cavity	60	0.35	Spreader, 1/2 holes	-10		

Note1: The results of the various alternatives will be examined and progressively compared to the generic wing temperature profile to decide further direction for testing. Some tests will be duplicated if they show promising results. Other variations may be introduced at any time depending on outcomes

Note2: The base case for spreader rate is 1/2 of the drain holes operational to conform to the rate selected for the outdoor test procedure

Table D-2
Test Record (further tests as decided)

Run	Surface	Fluid Temp (°C)	Fluid Qty (L)	Application type	Ambient Temp (°C)	Start Time	Comments

RESULTS

TYPE I FLUID TRIALS FOR LABORATORY PROCEDURE
PMG DECEMBER 2001

TYPE I TRIALS FOR LAB PROCEDURE
PMG DEC 2001
Log of Tests Conducted

Variation	Surface	Fluid Temp (°C)	Fluid Qty (L)	Application Type	Ambient Temp (°C)	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
1	Std plate (3.2 mm)	20	1.0	Std Pour (1/3 – 2/3)	-10	P1	P1				
2	Plate (3.2 mm)	20	1.0	Spreader, ½ holes	-10	P2	P2				
3	Plate (3.2 mm)	20	1.0	Spreader, ¼ holes	-10		P3				
4	Plate (3.2 mm)	20	1.0	Spreader, ¼ holes	-10			P1	P1		
5	Plate (3.2 mm)	60	0.5	Spreader, ½ holes	-10	P3		P2			
6	7.5 cm Insulated Cold-soak Box	60	0.5	Spreader, ½ holes	-10		P5				
7	7.5 cm Insulated Cold-soak Box	60	0.25	Spreader, ½ holes	-10		P6			P2	
8	7.5 cm Insulated Cold-soak Box	60	0.25	Spreader, all holes	-10			P5	P5	P5	
9	7.5 cm Insulated Cold-soak Box	60	0.25	Spreader, double holes	-10			P6		P3	
10	7.5 cm Insulated Cold-soak Box	60	0.35	Spreader, ½ holes	-10						
11	7.5 cm Insulated Cold-soak Box	60	0.35	Spreader, all holes	-10						
12	7.5 cm Insulated Cold-soak Box	60	0.35	Spreader, double holes	-10						
13	Cold-soak Box, no insulation	60	0.25	Spreader, all holes	-10		P4			P4	
14	Cold-soak Box, no insulation	60	0.35	Spreader, all holes	-10				P4		
15	Cold-soak Box, no insulation	60	0.25	Spreader, double holes	-10			P4			
16	Cold-soak Box, no insulation	60	0.35	Spreader, double holes	-10				P2		
17	Cold-soak Box	60	0.1	Sprayed	-10						
18	Cold-soak Box	60	0.25	Sprayed	-10						
19	Cold-soak Box	60	0.35	Sprayed	-10						
20	Cold-soak Box	60	0.5	Sprayed	-10					P1	

TYPE I TRIALS FOR LAB PROCEDURE
PMG DEC 2001
Log of Tests Conducted

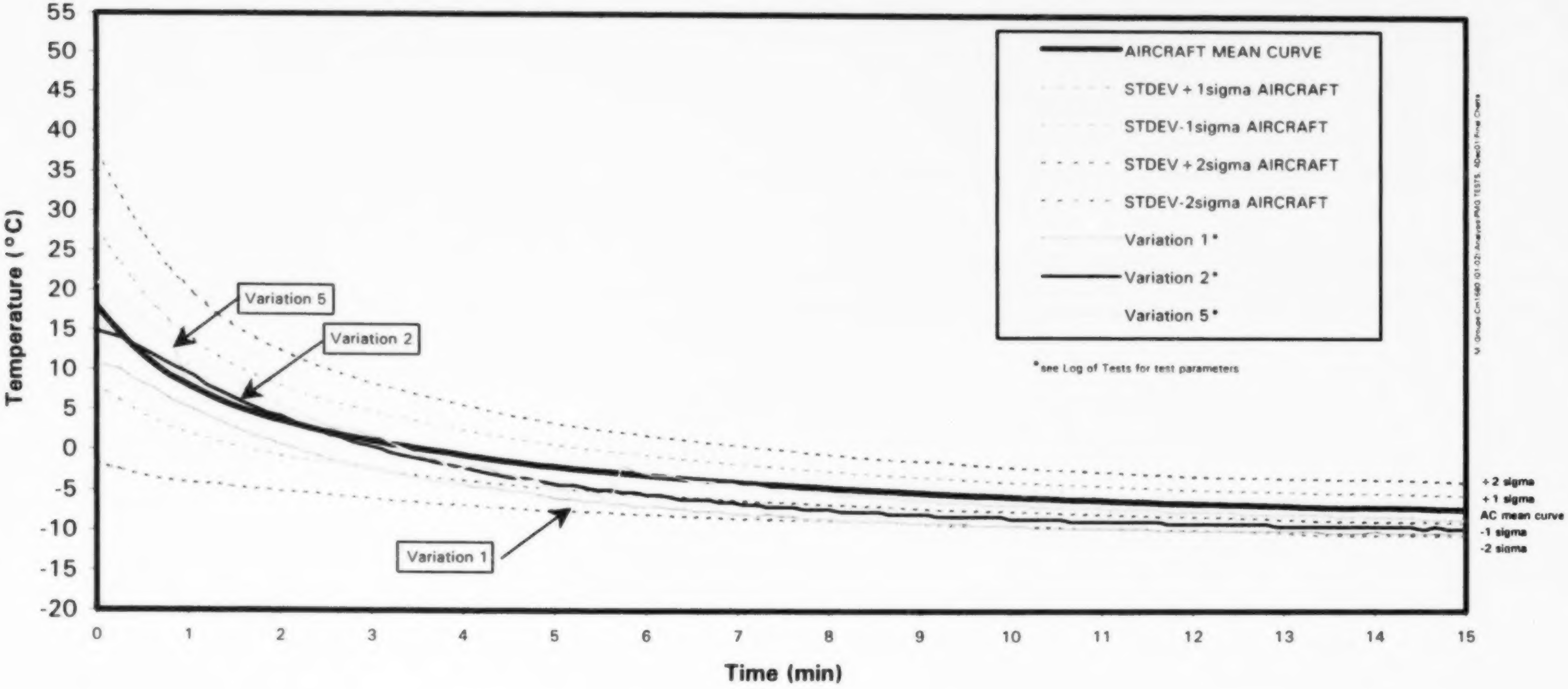
Variation	Surface	Fluid Temp (°C)	Fluid Qty (L)	Application Type	Ambient Temp (°C)	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
21	Cold-soak Box, 4.8 mm thick surface	60	0.5	Spreader, ½ holes	-10			P3			
22	Cold-soak Box, 4.8 mm thick surface	60	0.5	Spreader, ¼ holes	-10						
23	Cold-soak Box, 4.8 mm thick surface	60	0.75	Spreader, ½ holes	-10				P3		
24	Cold-soak Box, no insulation, 50% filled with -10°C fluid	60	0.25	Spreader, ½ holes	-10						
25	Cold-soak Box, no insulation, 50% filled with -10°C fluid	60	0.35	Spreader, ½ holes	-10						
26	Cold-soak Box, thick surface, 100% filled with -10°C fluid	60	0.25	Spreader, ½ holes	-10						
27	Cold-soak Box, thick surface, 100% filled with -10°C fluid	60	0.5	Spreader, ½ holes	-10						
28	Cold-soak Box, no insulation, with air blown through cavity	60	0.25	Spreader, all holes	-10					P6	
29	Cold-soak Box, no insulation, with air blown through cavity	60	0.5	Spreader, ½ holes	-10				P6		
30	CSB with insulation	60	0.2	Spreader, all holes	-10						P1
31	CSB without insulation	60	0.2	Spreader, all holes	-10						P2
32	CSB with insulation	60	0.2	Spreader, all holes	-10						P3
33	CSB without insulation	60	0.2	Spreader, all holes	-10						P4

P = position on stand

Comparison of Proposed Surfaces to Wing Leading Edge

Adjusted to OAT -10°C

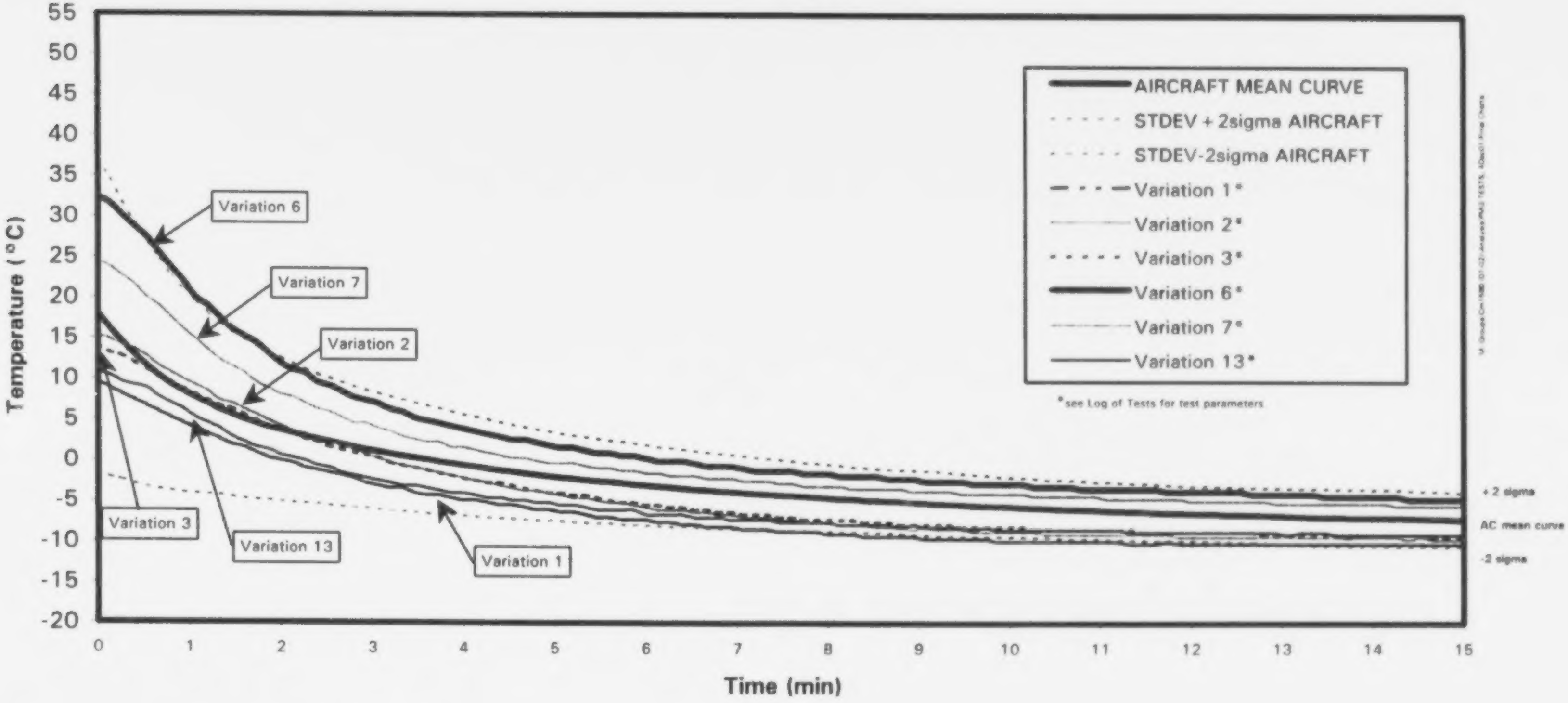
RUN #1



Comparison of Proposed Surfaces to Wing Leading Edge

Adjusted to OAT -10°C

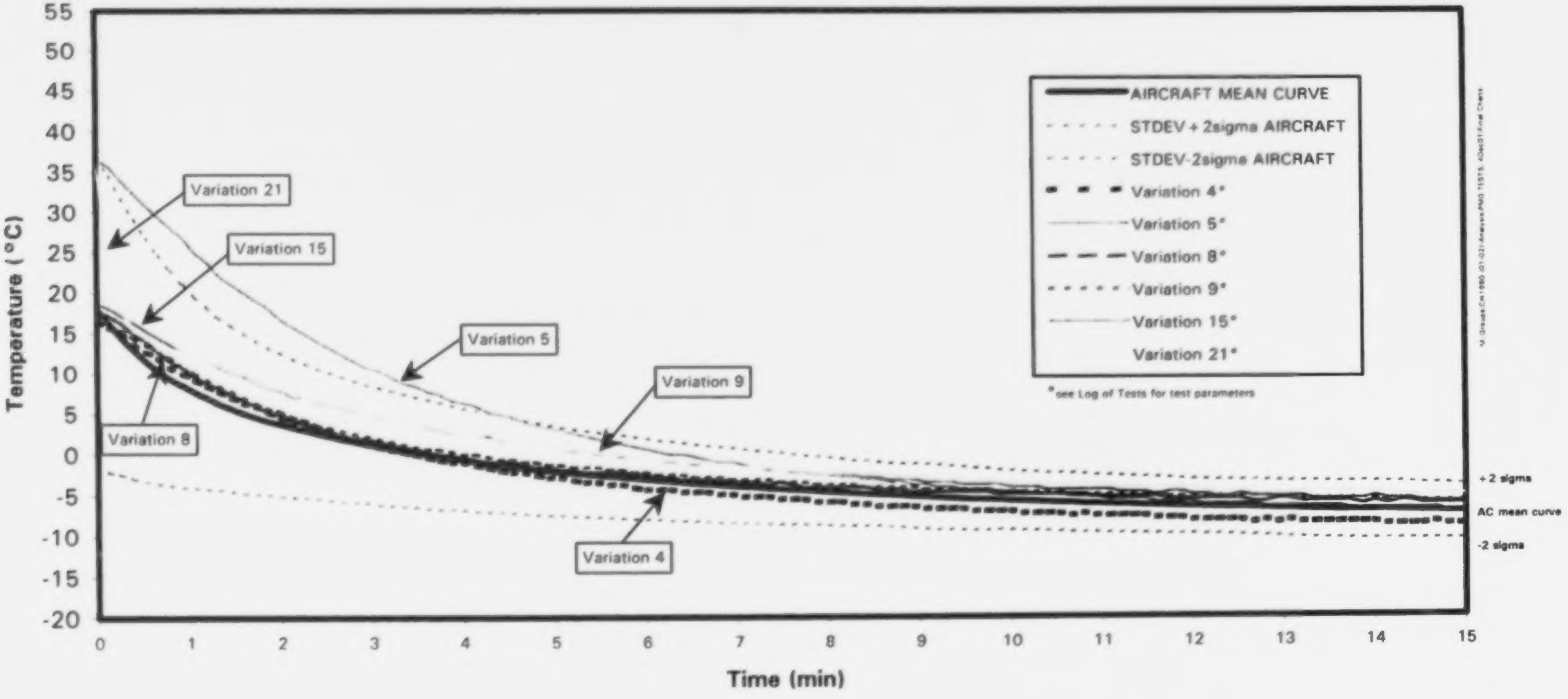
RUN #2



Comparison of Proposed Surfaces to Wing Leading Edge

Adjusted to OAT -10°C

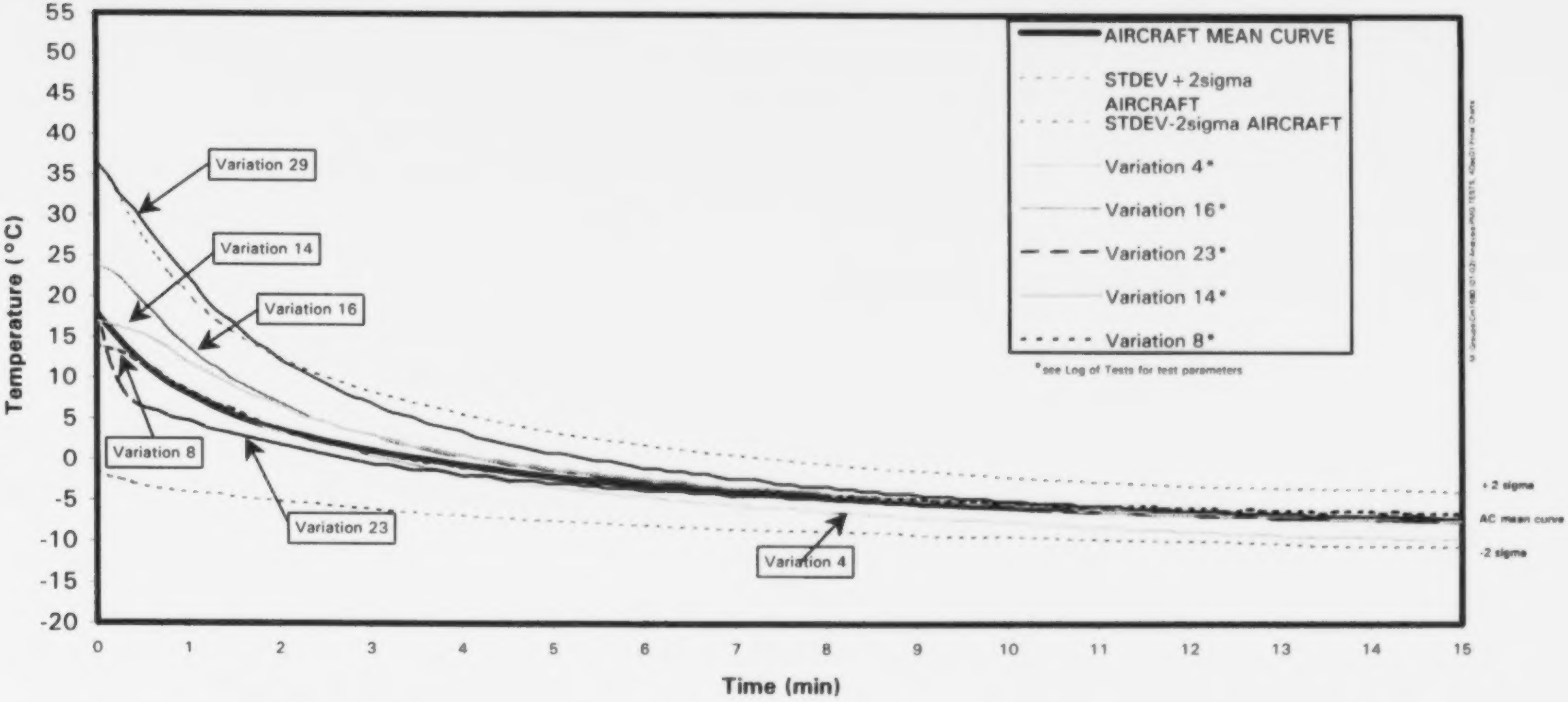
RUN #3



Comparison of Proposed Surfaces to Wing Leading Edge

Adjusted to OAT -10°C

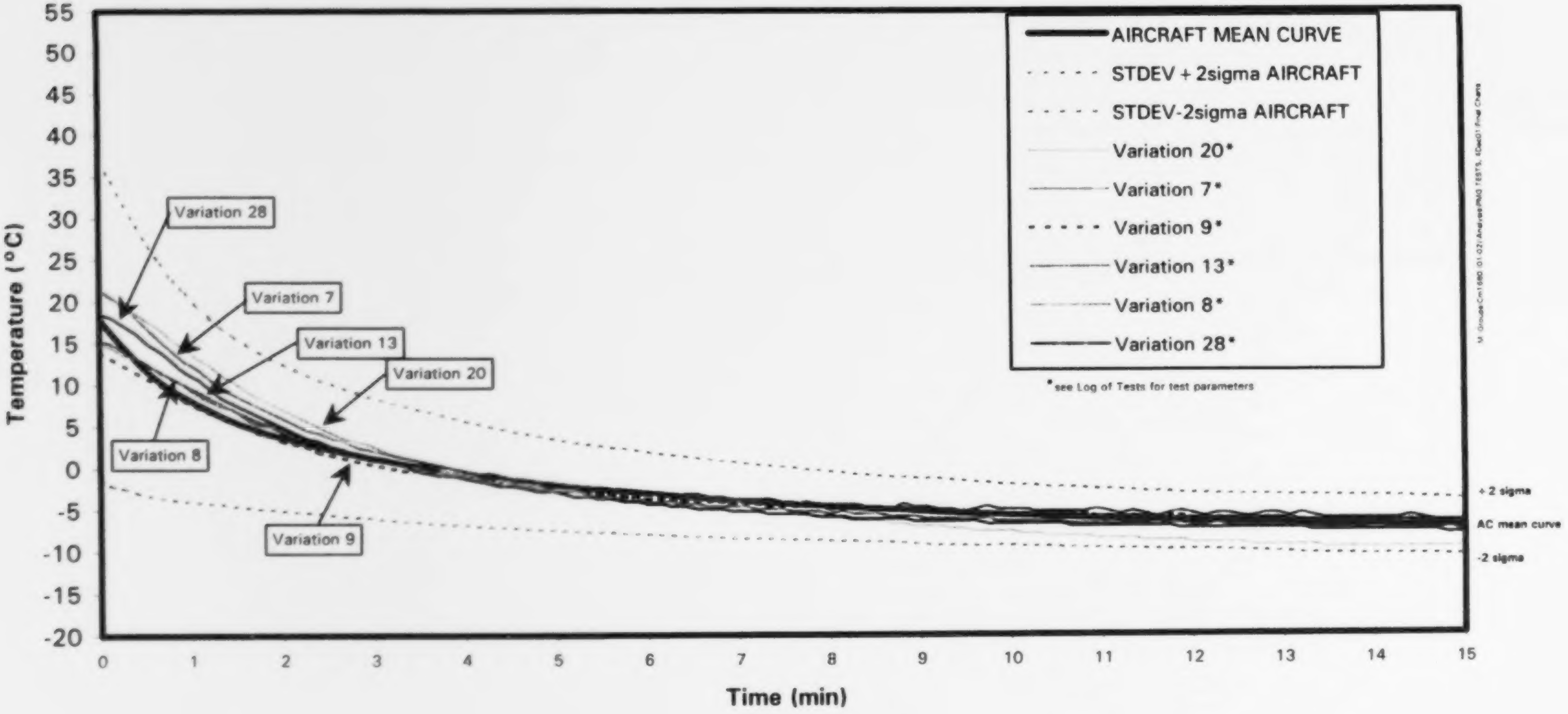
RUN #4



Comparison of Proposed Surfaces to Wing Leading Edge

Adjusted to OAT -10°C

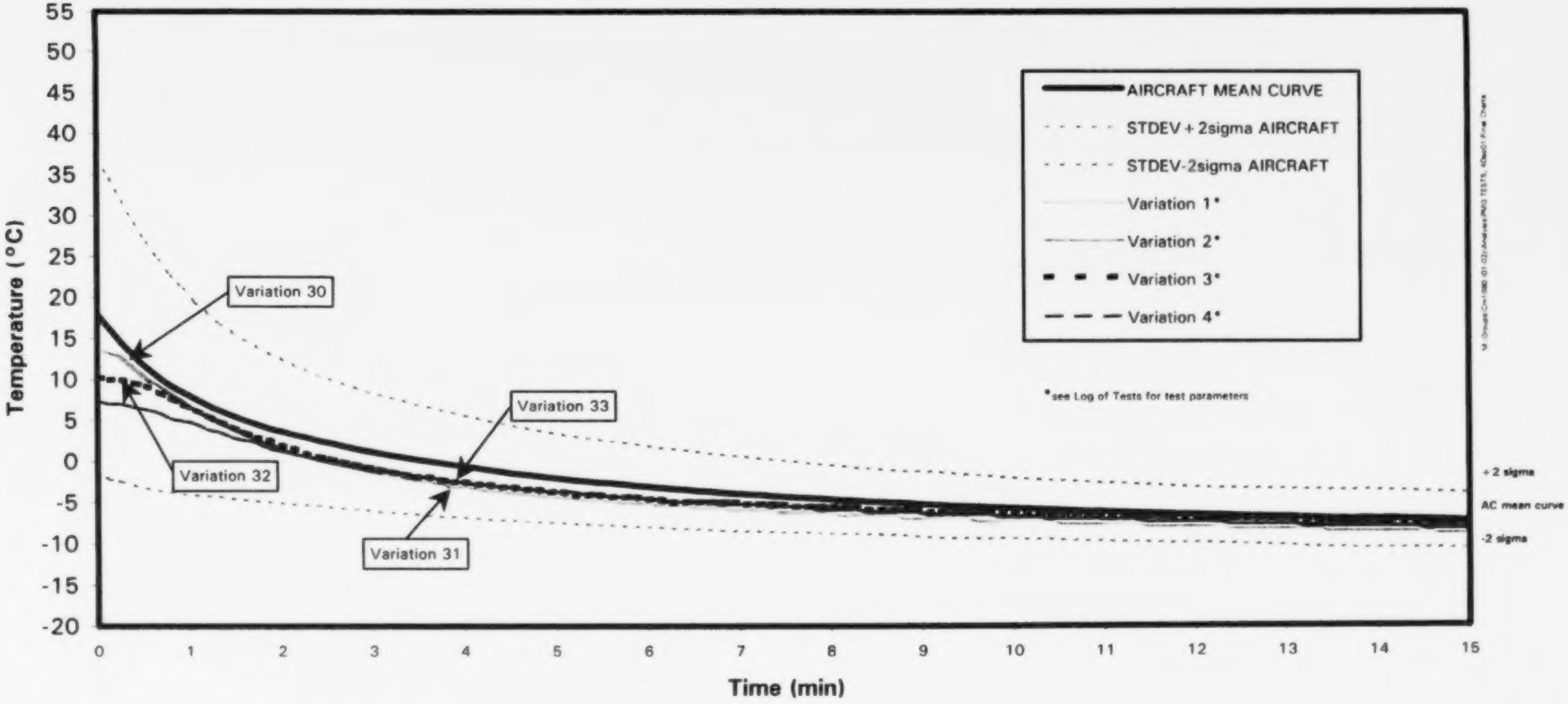
RUN #5

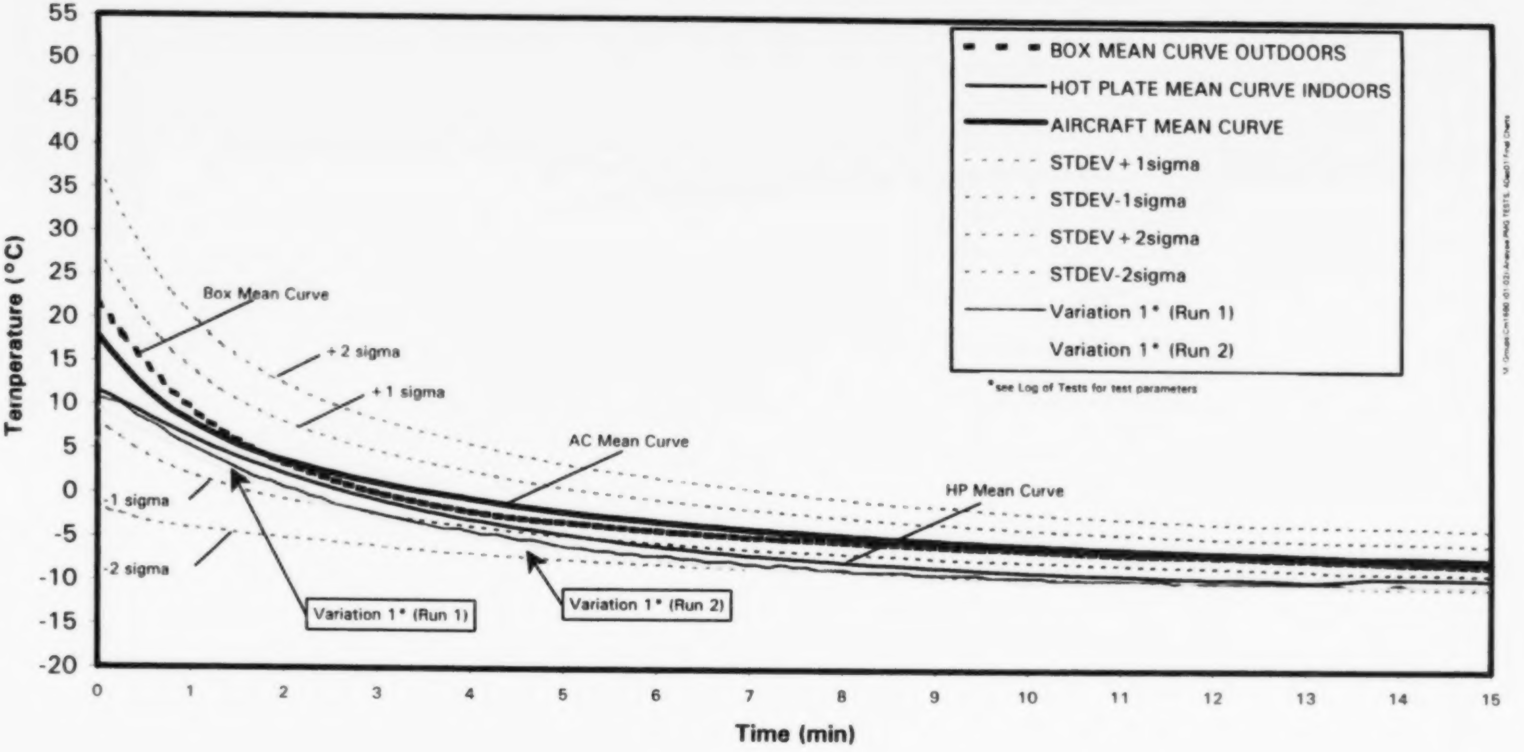


Comparison of Proposed Surfaces to Wing Leading Edge

Adjusted to OAT -10°C

RUN #6

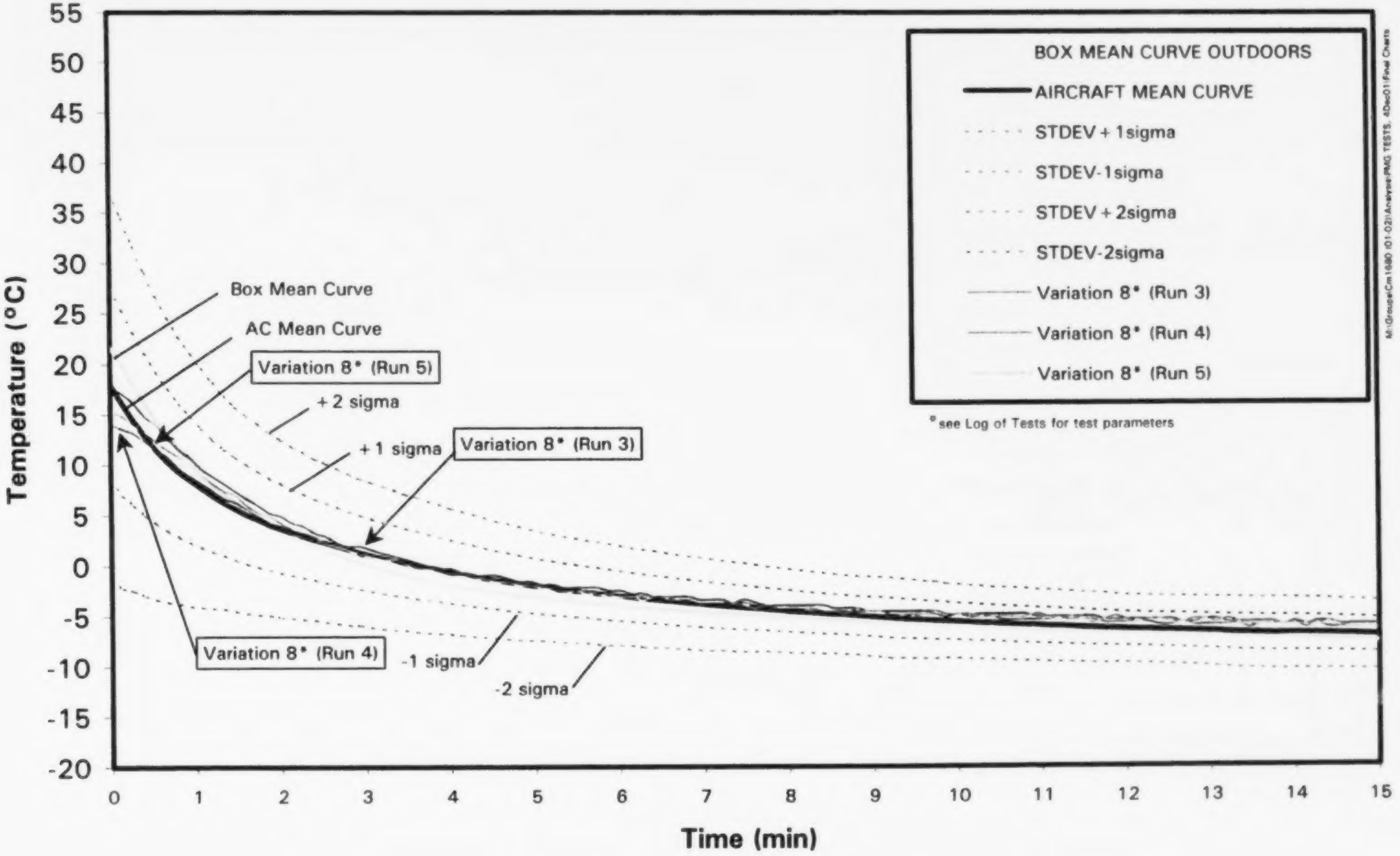




Temperature Profiles - Comparison to Average Wing and Box
Adjusted to OAT -10°C

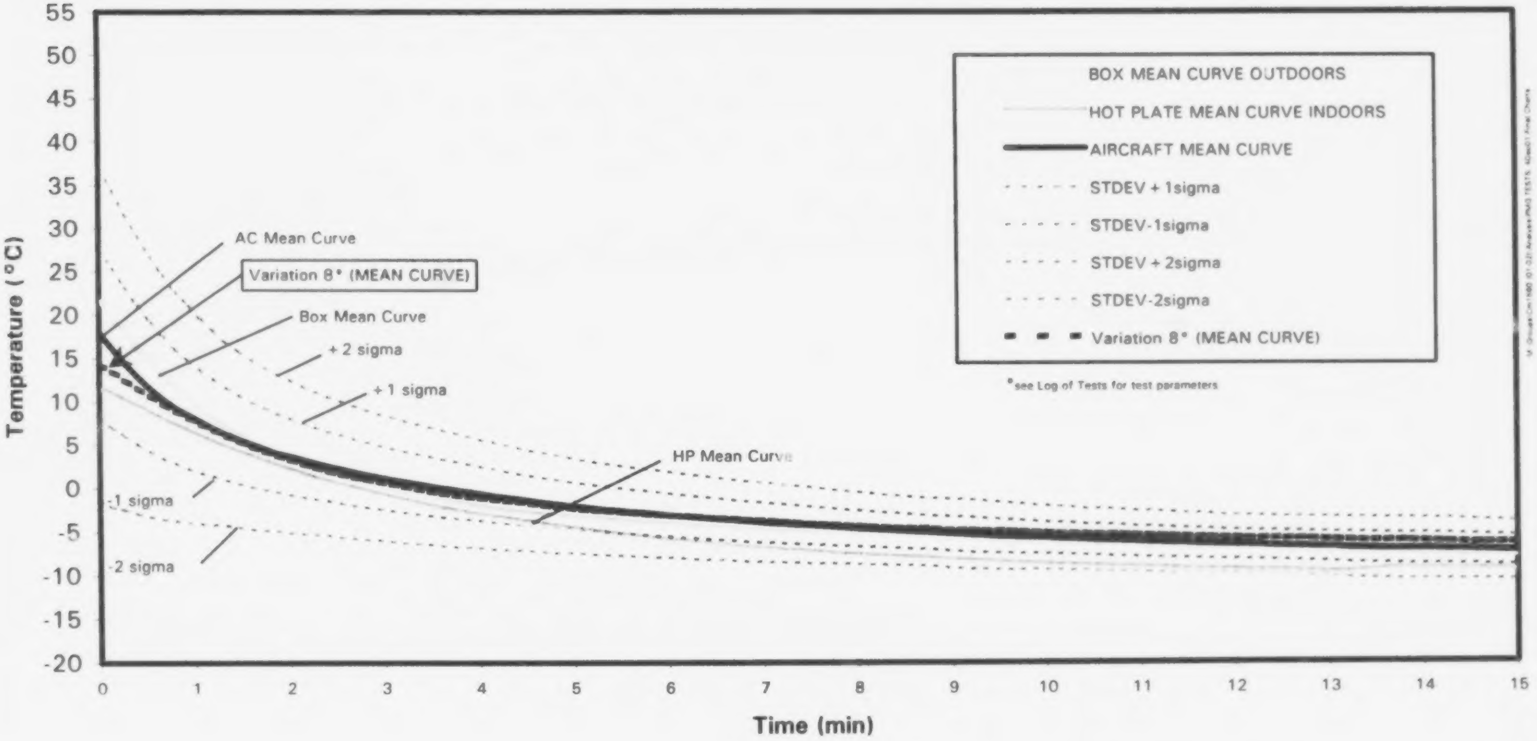
Temperature Profiles - Comparison to Average Wing and Box

Adjusted to OAT -10°C



Temperature Profiles - Comparison to Average Wing and Box

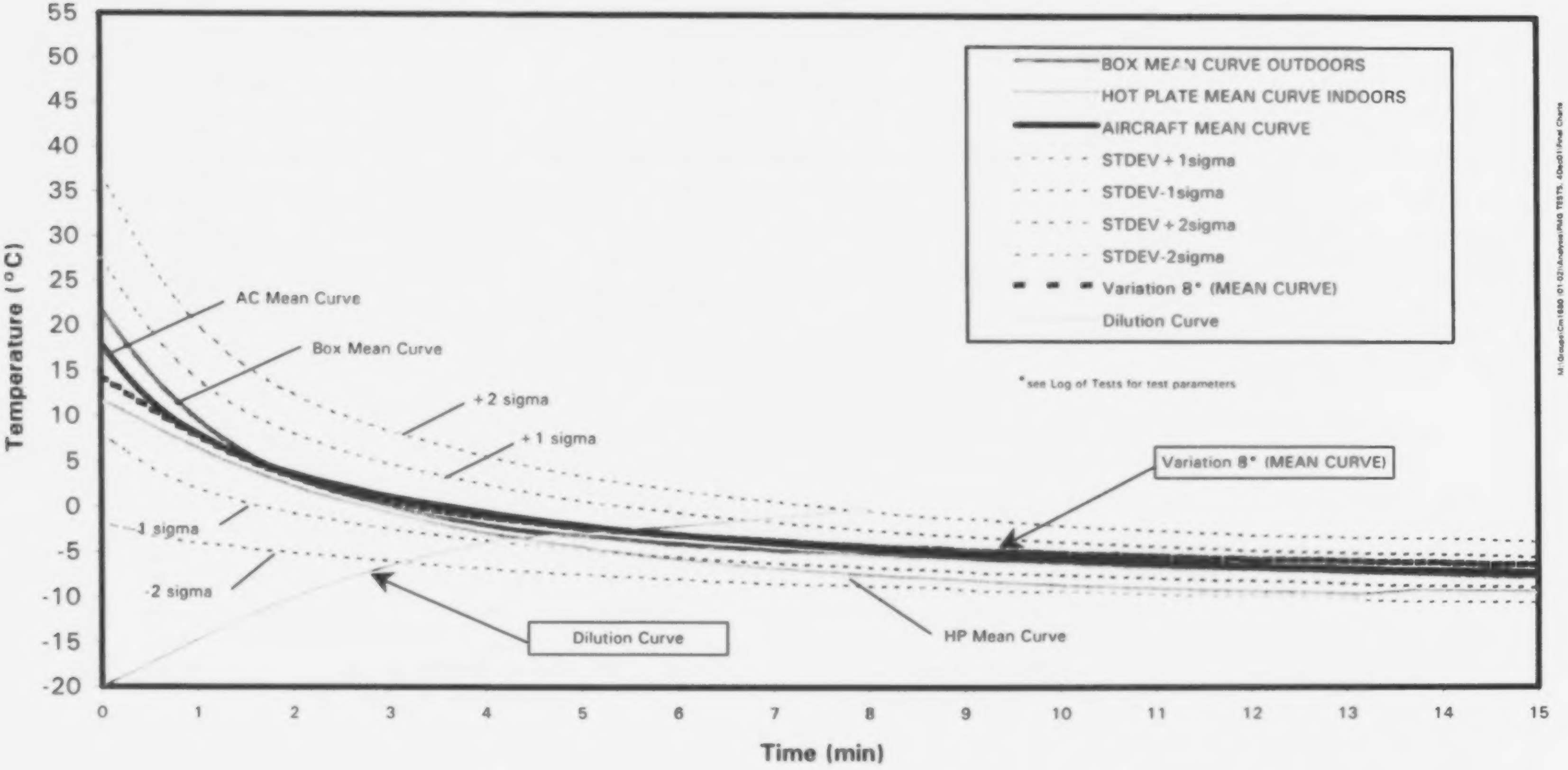
Adjusted to OAT -10°C



*see Log of Tests for test parameters

Temperature Profiles - Comparison to Average Wing and Box

Adiusted to OAT -10°C



*see Log of Tests for test parameters

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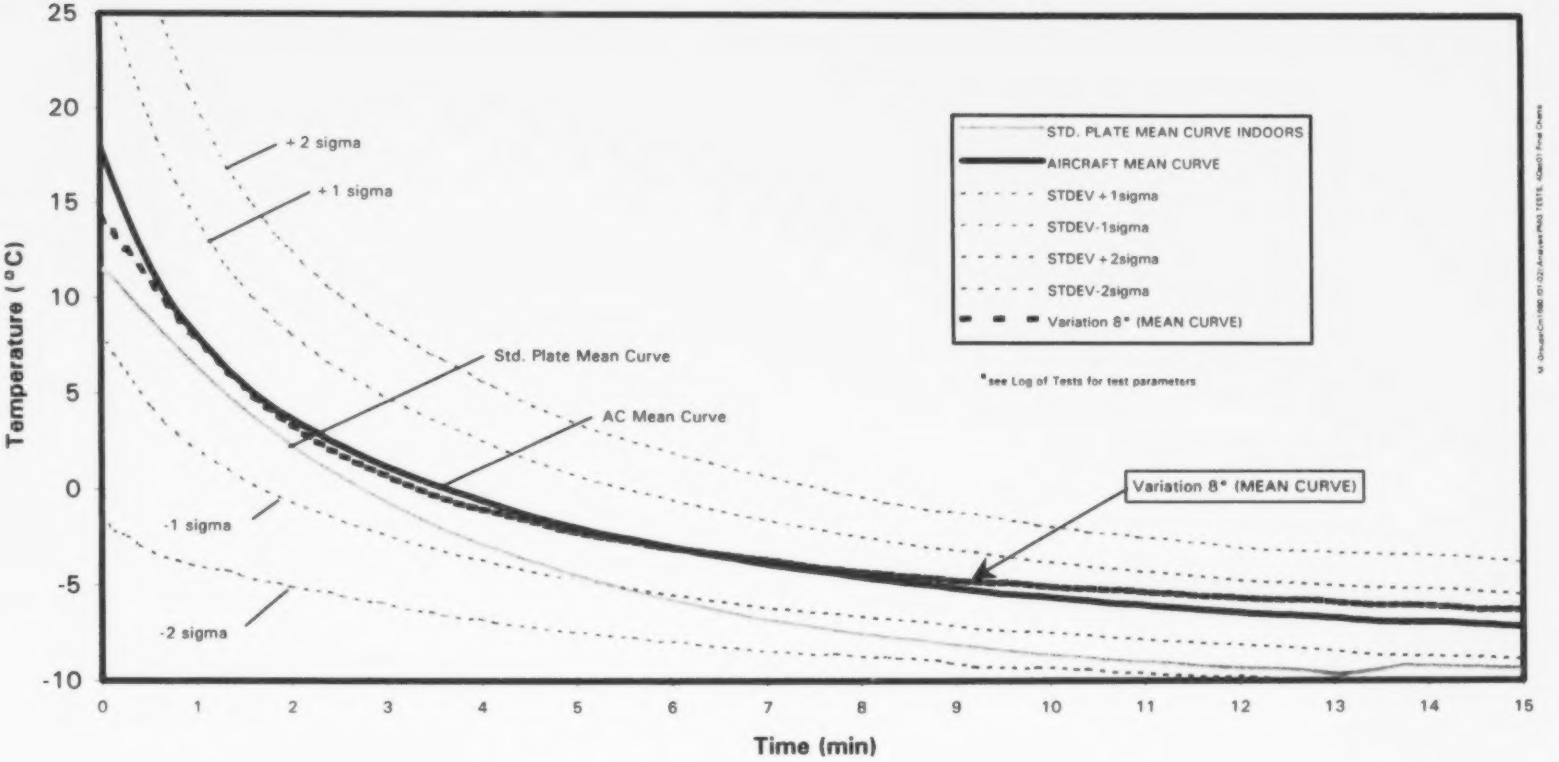
Temperature Profiles - Comparison to Average Wing and Box

Adjusted to OAT -10°C



E

APPENDIX E

DETERMINATION OF INDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL

- PROCEDURE
- RESULTS

CM1680.001

EXPERIMENTAL PROGRAM
DETERMINATION OF INDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL

- Freezing Fog
- Freezing Drizzle and Light Freezing Rain
- Rain on a Cold-Soaked Surface

Prepared by: Nicoara Moc NM
Reviewed by: John D'Avirro

APS AVIATION INC. APS

December 10, 2001
Version 1.1

EXPERIMENTAL PROGRAM
DETERMINATION OF INDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL

This document describes the detailed procedures and equipment required for the conduct of freezing fog, freezing drizzle, light freezing rain and rain on a cold-soaked surface endurance time tests. These tests will be conducted at NRC's Climatic Engineering Facility (CEF) in Ottawa.

1. BACKGROUND

Endurance Time tests have traditionally used flat plates as testing surfaces. In a study completed after the 2000-2001 winter (TP 13827E) it was concluded that the Type I test procedure with flat plates, when conducted outdoors in natural wind did not provide a good simulation of actual deicing operations and did not produce a surface temperature decay rate that matched real wings. Shortened fluid endurance times would result. A new protocol that would more closely simulate Type I anti-icing operations under natural conditions was developed to address these deficiencies.

Following examination of several test surfaces and various procedures for fluid application, it was concluded that a 7.5 cm cold-soak box, empty, when treated with 0.5 L of fluid at 60°C, produced a reasonable representation of the temperature decay rate demonstrated by wing leading edges in natural outdoor conditions.

Subsequent to these findings for the outdoor tests, the FAA requested that a similar protocol be developed for indoor tests. To address this, APS recently (December, 2001) carried out surface temperature profile tests at the PMG Facility, in Blainville, Quebec. The indoor tests showed that the cold-soak box test surface would still follow the desired temperature profile if the fluid quantity was decreased to 0.25L and the number of holes in the spreader is increased from 12 to 24.

2. OBJECTIVES

The objective of this test program is to establish indoor endurance times for Type I over the full range of HOT table conditions. The tests will be conducted on both standard endurance time plates and cold soak boxes. Testing will be conducted using the newly developed (PMG) test protocol that uses the box with 0.25 L of heated fluid. Scheduling of the indoor tests will be coordinated with the NRC. It is anticipated that the tests will begin on December 17, 2001. Duration of tests will be three or four working days, including set-up time. Fluid failure will be determined by visual observation.

As a supplementary objective, dilution measurements will be made on separate cold soak box. Also, temperature profiles will be measured on one cold soak box and one plate. These tests will be done at the same time as the endurance time trials and using the same fluids.

The anticipated schedule of tests is also provided in this document (See Attachment E-I).

As well, exploratory tests to examine the effect of testing heated dilute Type IV fluid endurance times in accordance with the new test protocol are included for several test conditions. These tests will be conducted on both the standard endurance time plate and the cold-soak box.

3. PERSONNEL

The personnel required is provided below:

3.1 Endurance time tests:

Coordinator (JD):	Conduct Tests
Leader (RC or AA):	Determine test fluids and positioning of tests on stand. Determine endurance times.
Computer Technician (MH):	Enter data (rate and failure times) as collected.
Weigh Scale Technician (YOW1):	Measure precipitation rates; complete general forms. Assist in test preparation
Fluids Manager (NB):	Measure Brix at pour; measure temperature at pour; prepare fluids for next tests.
Fluid Application (ML2):	Ensure plates are clean; application of fluids.

	Dilution tests
Manager (PD):	Determine test fluids and positioning of tests on stand; Manage tests.
Data Analysis (NM):	Analyze the data from the loggers and plot dilution charts.

4. PROCEDURES

4.1 Endurance time tests

For the ET plate baseline tests, the fluid temperature is 20°C and the quantity is 1.0 L. The Type I fluid will be diluted to a freeze point 10°C below ambient temperature.

For the 7.5 cm cold-soak box, the recommended fluid temperatures are 60°C with an acceptance range of +2°C and -0°C. The recommended quantity is 0.25 L, and the fluid will be applied on the surface through a spreader with 24 holes. The fluid used will be diluted to a freeze point 10°C below ambient temperature and also to a standard mix (DOW XL54 will be used).

The fluid will be mixed to a specific temperature dilution as per Attachment E-IV. A brixometer will be used to verify the dilution.

In addition to the regular test temperatures for Type I fluids, tests will be carried out at -3°C, as shown in the Test Plan (Attachment E-II).

The tests will be conducted using propylene-based (Lyondell Arco Plus) and ethylene-based (DOW ADF) Type I fluids, according to the Test Plan.

4.2 Dilution tests

The procedure is the same as for Section 4.1 with the exception that no endurance times will be measured. These tests will be conducted on a cold-soak box loaded with warm (+5°C) fluid to allow measurement of fluid concentration without interruption due to freezing. Brix measurements will be taken over the course of the tests. The plate/box temperature profiles will be recorded using thermistor loggers and charted against dilution curves. In the Test Plan (Attachment E-II), these tests are identified by the letter "R" preceding the test number.

4.3 Endurance Tests on Heated Dilute Type IV Fluid

Supplementary tests to examine the effect of testing dilute heated Type IV fluid with the new test protocol will use Kilfrost ABC-S 50/50 fluid. In the Test Plan (Attachment E-II), these tests are identified by the letter "S" preceding the test number.

5. TEST PLAN

The test schedule for CEF tests and the detailed test plan are included in this document. See Attachment E-I and Attachment E-II.

The arrangement of test surfaces on the test stands is illustrated in Attachment E-V.

6. EQUIPMENT

Test equipment required for the flat plate tests was determined from previous winters in association with the Society of Automotive Engineers (SAE) working group on ground deicing. The complete equipment list for CEF tests is shown in Attachment III. The list includes the equipment that is necessary for the tests to be carried out using the new test protocol.

7. DATA FORMS

The data forms for tests conducted in simulated conditions are as follows:

- General Form For Each Session At NRC, Form 1;
- Test Stand Location For Each Condition, Form 2;
- General Form For Each Condition, Form 3;
- Chamber Settings For Each Condition, Form 4;
- De/anti-icing Data Form For Freezing Precipitation, Form 5;
- Rate Management Form, Form 6; and
- Brix Measurement Form, Form 7.

FORM 1
GENERAL FORM FOR EACH SESSION AT NRC

LOCATION: CEF (Ottawa) **DATE INTERVAL:**

Safety Issues Discussed ☐

Test Plate Material: ☐
(check the box if material used is Aluminum alloy AMS 4037)

Test Plate Dimensions: ☐
(check the box if the dimensions are 500mm long x 300mm wide x 3.2mm thick)

Test Box Dimensions: ☐
(only for CSW, check the box if the dimensions are 500mm long x 300mm wide x 75mm thick)

Surface Finish: ☐
(check the box if the average surface roughness is less then or equal to 0.5 µm)

Ice-catch Pan Dimensions: ☐
(check the box if the dimensions are 406mm long x 279mm wide with a 64mm height)

Water Supply to Nozzle: ☐
(check the box if the water is ASTM D1193, Type IV)

Weigh Scale verification: 2g ☐ 100 g ☐
(see calibration procedure)

Air Temperature (°C):
(to be recorded by the NRC at a sampling rate of minimum 1 datum per minute and handed in to APS at the end of the session on floppy disks)
The air temperature data is saved to the following files (provide filename and extension):

Relative humidity (%):
(to be recorded by the NRC and handed in to APS at the end of the session on floppy disks)
The humidity data is saved to the following files (provide filename and extension):

COMMENTS:

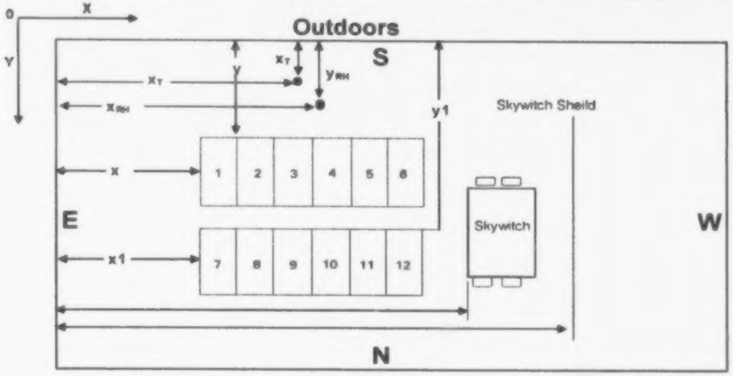
LEADER: ____________________

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC, Dec17\Forms\Form 1

FORM 2
TEST STAND LOCATION FOR EACH CONDITION

LOCATION: CEF (Ottawa)	DATE:	CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL

Test	Date of Final Position	Condition	T / RH				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						
1	4-Apr-01	ZR3H					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
2	4-Apr-01	ZR3L					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
3	4/2/2001	ZR10H					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft. from snow fence
4	2-Apr-01	ZR10L					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft. from snow fence
5	27-Mar-01	ZD3H					24' 5"	6'6"	22'	10'4"				Very Good		
6	28-Mar-01	ZD3L					25' 3"	7'3"	25' 3"	9' 6"				Good		
7	2-Apr-01	ZD10H					24'	7'11"	25' 3"	9' 6"				Very Good		
8	2-Apr-01	ZD10L					24'	7' 7"	24' 7"	9' 11"				Good		20 ft. from Snow Fence
9	10-Apr-01	ZFog3H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
10	10-Apr-01	ZFog3L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
11	10-Apr-01	ZFog10H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
12	10-Apr-01	ZFog10L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
13	9-Apr-01	ZFog14H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
14	9-Apr-01	ZFog14L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
15	6-Apr-01	ZFog25H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
16	6-Apr-01	ZFog25L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
17	29-Mar-01	CSWH					25'3"		25'3"	9' 6"						
18	29-Mar-01	CSWL					23'11"	7'3"	25'3"	9' 6"						



Notes:
* - "From X" refers to the distance from the East wall
** - The nozzle should be between positions 5 and 11
RH - Relative Humidity Sensor
T - Temperature Sensor

WEIGH SCALE TECHNICIAN: ____________________

LEADER: ____________________

NEW VALUES (IF DIFFERENT)

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						

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FORM 3
GENERAL FORM FOR EACH CONDITION

LOCATION: CEF (Ottawa)	**DATE:**	**CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L** **ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL**

	PLATE 1	PLATE 6	PLATE 7	PLATE 12
Angle of the Test Stands (°):	☐	☐	☐	☐

Distance between Nozzle and Test Plates (m): ☐
(check the box if distance is 144" for ZF and 7±0.5m for ZD, ZR and CSW)

Plate Temperature (°C):
(to be recorded by APS at the end of the each condition, saved on floppy disks and included in the envelope along with the forms)
The plate temperature data is saved to the following files (provide filename and extension):

COMMENTS:

COMPUTER TECHNICIAN: ____________

LEADER: ____________

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC, Dec17\Forms\Form 3

FORM 4
CHAMBER SETTINGS FOR EACH CONDITION

LOCATION: CEF (Ottawa)	DATE:	CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL

CONDITION	Needles Used	Flow Rate of Water *	Line Air Pressure (psi)	Line Air Temperature (Celsius)	Line Water Pressure (psi)	Line Water Temperature (Celsius)	Relative Humidity (%)	X Axis Area	Speed	Y Axis Area	Speed	Brace Height (inches)	LT'S on						MT'S on						Last Date
													1	2	3	4	5	6	1	2	3	4	5	6	
ZR 3 L	**2x20**	**1 GPM**	**60**	**12.5**	**78**	**2**	**75**	**full**	**low**	**full**	**high**		**y**	**y**					**y**	**y**	**y**				**4-Apr-01**
ZR 10 L	2x20	1 GPM	60	12.5	82	2.5	75	full	low	full	high			y					y	y	y				3-Apr-01
ZR 3 H	**2x20**	**1 GPM**	**60**	**12.5**	**61**	**2**	**75**	**partial**	**low**	**full**	**high**								**y**	**y**	**y**				**4-Apr-01**
ZR 10 H	2x20	1 GPM	60	12.5	78	2.5	73	partial	low	full	high			y					y	y	y				3-Apr-01
ZD 3 L	2x24	1 GPM	60	13	65	2.5	75	partial	low	full	high								y	y	y				28-Mar-01
ZD 10 L	2x24	1 GPM	60	12	43	2	76	full	low	full	high			y					y	y	y				30-Mar-00
ZD 3 H	2x23	1 GPM	60	13	62	2.5	90	partial	low	full	high								y	y	y				27-Mar-01
ZD 10 H	2x23	1 GPM	60	12	55	2.5	72	partial	low	full	high		y	y					y	y	y				30-Mar-00
FOG 3 L	1 X 20/50/120	80	80	80	-	73.3	96	full	low	full	low	144							y	y	y				5-Apr-01
FOG 14 L	1 x 20/50/120	55	40	72	-	72.8	80	full	low	full	low	144							Y	Y	Y				11-Apr-01
FOG 25 L	1 x 20/50/120	50	40	72	-	72.8	80	full	low	full	low	144	y	y	y										6-Apr-01
FOG 3 H	1X 20/50/120	75	40	72	-	73.2	95	full	low	full	low	144							y	y	y				10-Apr-01
FOG 14 H	1 x 20/50/120	75	40	73	-	72.8	76	full	low	full	low		y						y	y	y				9-Apr-01
FOG 25 H	1 x 20/50/120	75	40	73	-	73.2	73	full	low	full	low	144	y	y	y										6-Apr-01
CSW 1 H	2x17	1 GPM	60	13.5	75	2	85	part	low	full	high										y	y		y	4-Jun-01
CSW 1 L	2 x 24	1 GPM	60	12.5	30	2.5	89	full	low	full	high										y	y			4-Jun-01
ZD 10 5	2 x 24	1 GPM	60	15	35	4.5	-												y	y	y				16-Jul-99
FOG 35 H	1 X 20/50	12	40	74	-	-	-	partial	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 35 L	1 x 20/50	10	40	73	-	-	-	full	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 30 L	1 x 20/50	10	40	73	-	-	-	full	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 32 L	1 x 20/50	13	40	-	-	-	-	partial	low	full	low	104	y	y	y	y									20-Jul-99
FOG 32 H	1 x 20/50	24	40	-	-	-	-	full	low	full	low	144	y	y	y	y									20-Jul-99
FOG 10 H	1 x 20/50	75	40	74	-	72.6	-	full	low	full	low	144							y	y	y				9-Apr-01
FOG 10 L	1 X 20/50	55	40	-	-	-	-	full	low	full	low	144							y	y	y				9-Apr-01
FOG25L	1x20/50/120	15	40	73	-	70.9	-	full	low	full	low	144		y	y	y									31-Mar-00
FOG25h	1x20/50/120	24	40	79	-	72.9	-	full	low	full	low	144	y	y	y										4-Apr-00
ZR3H-2	2X20	1GPM	60	12.5	90	1.5	-	partial	low	full	high								y	y	y				6-Apr-00

* Dial Readings=X ⟶ Flow Rate for Fog (ml/min) = $0.0033*X^2 + 3.3605*X - 17.512$

Brace height 12'6"

NEW VALUES (IF DIFFERENT)

CONDITION	Needles Used	Flow Rate of Water*	Line Air Pressure (psi)	Line Air Temperature (Celsius)	Line Water Pressure (psi)	Line Water Temperature (Celsius)	Relative Humidity (%)	X Axis Area	Speed	Y Axis Area	Speed	Brace Height (inches)	LT'S on						MT'S on						Date
													1	2	3	4	5	6	1	2	3	4	5	6	

COMPUTER TECHNICIAN:________________________ LEADER: ________________________

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FO
DE/ANTI-ICING DATA FORM

REMEMBER TO SYNCHRONIZE TIME

LOCATION: CEF (Ottawa) **DATE:**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application: ______ ______ ______
Initial Fluid Temperature (°C) ______ ______ ______
Initial Plate/BOX Temperature (°C) ______ ______ ______
Initial Brix ______ ______ ______

	Plate/BOX #			Plate/BOX #			Plate	
FLUID NAME								
B1 B2 B3								
C1 C2 C3								
D1 D2 D3								
E1 E2 E3								
F1 F2 F3								

Final Temperature / Brix ☐☐ ☐☐ ☐

FAILURE CALL (circle) V Difficult Difficult Easy V Difficult Difficult Easy V Difficult D

HRZ. AIR VELOCITY * (circle) A B C A B C A

Time of Fluid Application: ______ ______ ______
Initial Fluid Temperature (°C) ______ ______ ______
Initial Plate/BOX Temperature (°C) ______ ______ ______
Initial Brix ______ ______ ______

	Plate/BOX #			Plate/BOX #			Plate	
FLUID NAME								
B1 B2 B3								
C1 C2 C3								
D1 D2 D3								
E1 E2 E3								
F1 F2 F3								

Final Temperature / Brix ☐☐ ☐☐ ☐

FAILURE CALL (circle) V Difficult Difficult Easy V Difficult Difficult Easy V Difficult D

HRZ. AIR VELOCITY * (circle) A B C A B C A

PRECIP (circle): ZF, ZD, ZR-, CSB **AMBIENT TEMPERATURE:** ______ °C

COMMENTS:

FORM 5

DATA FORM FOR FREEZING PRECIPITATION

VERSION 1.1 2001/2002

RUN NUMBER: STAND # :

te/BOX # Plate/BOX # Plate/BOX # Plate/BOX # Plate/BOX #

Difficult Easy V. Difficult Difficult Easy V. Difficult Difficult Easy V. Difficult Difficult Easy V. Difficult Difficult Easy

B C A B C A B C A B C A B C

te/BOX # Plate/BOX # Plate/BOX # Plate/BOX # Plate/BOX #

Difficult Easy V. Difficult Difficult Easy V. Difficult Difficult Easy V. Difficult Difficult Easy V. Difficult Difficult Easy

B C A B C A B C A B C A B C

PERATURE: ________ °C

NOTE:
- * A: HORIZONTAL AIR VELOCITY ≤ 0.4 m/s
- B: 0.4 m/s < HORIZONTAL AIR VELOCITY ≤ 1.0 m/s
- C: HORIZONTAL AIR VELOCITY > 1.0 m/s

LEADER / MANAGER: ____________________

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FORM 6
RATE MANAGEMENT FORM

DATE: ____________ **WEIGH SCALE TECHNICIAN:** ________________________

PAN #	TIME OUT	1st or 2nd Rate

PAN #	TIME OUT	1st or 2nd Rate

This form is for guidance to manage the sequencing of pans measurement.

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC, Dec17\Forms\Form 6

FORM 7
FLUID BRIX TEST

DATE: ______________

RUN #: ______________

STAND: ______________

PERFORMED BY: ______________

WRITTEN BY: ______________

LOCATION: ______________

<table>
<tr><th colspan="6">BRIX</th></tr>
<tr><td colspan="2">Plate:
Fluid:</td><td colspan="2">Plate:
Fluid:</td><td colspan="2">Plate:
Fluid:</td></tr>
<tr><th>TIME</th><th>6" LINE</th><th>TIME</th><th>6" LINE</th><th>TIME</th><th>6" LINE</th></tr>
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ATTACHMENT E-I
SCHEDULE OF TESTS

Dec 17, 2001
MONDAY

7^{AM}	
8^{00}	SETUP
9^{00}	ZR @ -10, 25
10^{00}	
11^{00}	ZR @ -10, 13
12^{PM}	ZD @ -10, 13
1^{00}	
2^{00}	ZD @ -10, 5
3^{00}	
4^{00}	Temperature Change (-10 to -3)
5^{00}	ZD @ -3, 5
6^{00}	ZD @ -3, 13
7^{00}	

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC. Dec17\Calendar

ATTACHMENT E-I
SCHEDULE OF TESTS

Dec 18, 2001
TUESDAY

7^{AM}	
8^{00}	STARTUP
9^{00}	CSW @ +1, 5
10^{00}	CSW @ +1, 75
11^{00}	
12^{PM}	Temperature Change (+1 to -3)
1^{00}	ZR @ -3, 13
2^{00}	ZR @ -3, 25
3^{00}	
4^{00}	Set Up for Zfog
5^{00}	
6^{00}	ZFog @ -3, 5
7^{00}	
8^{00}	Temperature Change (-3 to -25, overnight)

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC, Dec17\Calendar

ATTACHMENT E-I
SCHEDULE OF TESTS

Dec 19, 2001
WEDNESDAY

7^{AM}	
8^{00}	STARTUP
9^{00}	ZFog @ -25, 2
10^{00}	
11^{00}	ZFog @ -25, 5
12^{PM}	
1^{00}	Temperature Change (-25 to -10)
2^{00}	
3^{00}	ZFog @ -10, 5
4^{00}	
5^{00}	ZFog @ -10, 2
6^{00}	
	Temperature Change (-10 to -3)
7^{00}	
	ZFog @ -3, 2
8^{00}	

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC, Dec17\Calendar

ATTACHMENT E-II
CEF DETAILED TEST PLAN
Type I Fluids

Test #	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	Dilution [%] 10° Buffer XL54 Premix	Fluid Temp. [°C]	Fluid Initial Brix	Applic. Method	Quantity [L]	Glycol Type	Surface	HOT Est. (from prev. tests)	HOT
1	Cold Soak	+1	5	10°	20		Pour	1	UCAR ADF	Cold Soak Box	5	
2	Cold Soak	+1	5	10°	20		Pour	1	Lyondell Arco+	Cold Soak Box	5	
3	Cold Soak	+1	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
4	Cold Soak	+1	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
5	Cold Soak	+1	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
6	Cold Soak	+1	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
7	Cold Soak	+1	75	10°	20		Pour	1	UCAR ADF	Cold Soak Box	2	
8	Cold Soak	+1	75	10°	20		Pour	1	Lyondell Arco+	Cold Soak Box	2	
9	Cold Soak	+1	75	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
10	Cold Soak	+1	75	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
11	Cold Soak	+1	75	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
12	Cold Soak	+1	75	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
13	Freezing Drizzle	-3	5	10°	20		Pour	1	UCAR ADF	Plate		
14	Freezing Drizzle	-3	5	10°	20		Pour	1	Lyondell Arco+	Plate		
15	Freezing Drizzle	-3	6	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
16	Freezing Drizzle	-3	5	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
17	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
18	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
19	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
20	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
R1	Freezing Drizzle	-3	5	10°	20		Pour	1	UCAR ADF	Plate		
R2	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R3	Freezing Drizzle	-3	5	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R4	Freezing Drizzle	-3	5	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R5	Freezing Drizzle	-3	5	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
21	Freezing Drizzle	-3	13	10°	20		Pour	1	UCAR ADF	Plate		
22	Freezing Drizzle	-3	13	10°	20		Pour	1	Lyondell Arco+	Plate		
23	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
24	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
25	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
26	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
S1	Freezing Drizzle	-3	13	50/50	20		Pour	1	Kilfrost ABC-S 50/50	Plate		
S2	Freezing Drizzle	-3	13	50/50	60		Spreader	0.25	Kilfrost ABC-S 50/50	Cold Soak Box		
R6	Freezing Drizzle	-3	13	10°	20		Pour	1	UCAR ADF	Plate		
R7	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R8	Freezing Drizzle	-3	13	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R9	Freezing Drizzle	-3	13	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R10	Freezing Drizzle	-3	13	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
27	Freezing Drizzle	-10	5	10°	20		Pour	1	UCAR ADF	Plate	8	
28	Freezing Drizzle	-10	5	10°	20		Pour	1	Lyondell Arco+	Plate	8	
29	Freezing Drizzle	-10	5	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
30	Freezing Drizzle	-10	5	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
31	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
32	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		

ATTACHMENT E-II

CEF DETAILED TEST PLAN

Type I Fluids

Test #	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	Dilution [%] 10° Buffer XL54 Premix	Fluid Temp. [°C]	Fluid Initial Brix	Applic. Method	Quantity [L]	Glycol Type	Surface	HOT Est. (from prev. tests)	HOT
33	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
34	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
R11	Freezing Drizzle	-10	5	10°	20		Pour	1	UCAR ADF	Plate	8	
R12	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R13	Freezing Drizzle	-10	5	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R14	Freezing Drizzle	-10	5	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R15	Freezing Drizzle	-10	5	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
35	Freezing Drizzle	-10	13	10°	20		Pour	1	UCAR ADF	Plate	5	
36	Freezing Drizzle	-10	13	10°	20		Pour	1	Lyondell Arco+	Plate	5	
37	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
38	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
39	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
40	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
S3	Freezing Drizzle	-10	13	50/50	20		Pour	1	Kilfrost ABC-S 50/50	Plate		
S4	Freezing Drizzle	-10	13	50/50	60		Spreader	0.25	Kilfrost ABC-S 50/50	Cold Soak Box		
R16	Freezing Drizzle	-10	13	10°	20		Pour	1	UCAR ADF	Plate	5	
R17	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R18	Freezing Drizzle	-10	13	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R19	Freezing Drizzle	-10	13	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R20	Freezing Drizzle	-10	13	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
41	Freezing Fog	-3	2	10°	20		Pour	1	UCAR ADF	Plate		
42	Freezing Fog	-3	2	10°	20		Pour	1	Lyondell Arco+	Plate		
43	Freezing Fog	-3	2	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
44	Freezing Fog	-3	2	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
45	Freezing Fog	-3	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
46	Freezing Fog	-3	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
47	Freezing Fog	-3	2	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
48	Freezing Fog	-3	2	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
49	Freezing Fog	-3	5	10°	20		Pour	1	UCAR ADF	Plate		
50	Freezing Fog	-3	5	10°	20		Pour	1	Lyondell Arco+	Plate		
51	Freezing Fog	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
52	Freezing Fog	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
53	Freezing Fog	-3	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
54	Freezing Fog	-3	5	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
55	Freezing Fog	-10	2	10°	20		Pour	1	UCAR ADF	Plate	15	
56	Freezing Fog	-10	2	10°	20		Pour	1	Lyondell Arco+	Plate	15	
57	Freezing Fog	-10	2	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
58	Freezing Fog	-10	2	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
59	Freezing Fog	-10	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
60	Freezing Fog	-10	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
61	Freezing Fog	-10	2	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
62	Freezing Fog	-10	2	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
63	Freezing Fog	-10	5	10°	20		Pour	1	UCAR ADF	Plate	6	

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ATTACHMENT E-II
CEF DETAILED TEST PLAN
Type I Fluids

Test #	Precip Type	Test Temp. [°C]	Precip Rate [g/dm^2/h]	Dilution [%] 10° Buffer XL54 Premix	Fluid Temp. [°C]	Fluid Initial Brix	Applic. Method	Quantity [L]	Glycol Type	Surface	HOT Est. (from prev. tests)	HOT
64	Freezing Fog	-10	5	10°	20		Pour	1	Lyondell Arco +	Plate	6	
65	Freezing Fog	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
66	Freezing Fog	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
67	Freezing Fog	-10	5	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
68	Freezing Fog	-10	5	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
69	Freezing Fog	-25	2	10°	20		Pour	1	UCAR ADF	Plate	15	
70	Freezing Fog	-25	2	10°	20		Pour	1	Lyondell Arco +	Plate	15	
71	Freezing Fog	-25	2	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
72	Freezing Fog	-25	2	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
73	Freezing Fog	-25	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
74	Freezing Fog	-25	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
75	Freezing Fog	-25	2	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
76	Freezing Fog	-25	2	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
77	Freezing Fog	-25	5	10°	20		Pour	1	UCAR ADF	Plate	6	
78	Freezing Fog	-25	5	10°	20		Pour	1	Lyondell Arco +	Plate	6	
79	Freezing Fog	-25	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
80	Freezing Fog	-25	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
81	Freezing Fog	-25	5	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
82	Freezing Fog	-25	5	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
83	Light Freezing Rain	-3	13	10°	20		Pour	1	UCAR ADF	Plate		
84	Light Freezing Rain	-3	13	10°	20		Pour	1	Lyondell Arco +	Plate		
85	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
86	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
87	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
88	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
S5	Light Freezing Rain	-3	13	50/50	20		Pour	1	Kilfrost ABC-S 50/50	Plate		
S6	Light Freezing Rain	-3	13	50/50	60		Spreader	0.25	Kilfrost ABC-S 50/50	Cold Soak Box		
R21	Light Freezing Rain	-3	13	10°	20		Pour	1	UCAR ADF	Plate		
R22	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R23	Light Freezing Rain	-3	13	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R24	Light Freezing Rain	-3	13	10°	20		Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box		
R25	Light Freezing Rain	-3	13	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
89	Light Freezing Rain	-3	25	10°	20		Pour	1	UCAR ADF	Plate		
90	Light Freezing Rain	-3	25	10°	20		Pour	1	Lyondell Arco +	Plate		
91	Light Freezing Rain	-3	25	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
92	Light Freezing Rain	-3	25	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
93	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
94	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
95	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
96	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	Lyondell Arco +	Cold Soak Box		
R26	Light Freezing Rain	-3	25	10°	20		Pour	1	UCAR ADF	Plate		
R27	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R28	Light Freezing Rain	-3	25	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		

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ATTACHMENT E-II

CEF DETAILED TEST PLAN

Type I Fluids

Test #	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	Dilution [%] 10° Buffer XL54 Premix	Fluid Temp. [°C]	Fluid Initial Brix	Applic. Method	Quantity [L]	Glycol Type	Surface	HOT Est. (from prev. tests)	HOT
R29	Light Freezing Rain	-3	25	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R30	Light Freezing Rain	-3	25	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
97	Light Freezing Rain	-10	13	10°	20		Pour	1	UCAR ADF	Plate	5	
98	Light Freezing Rain	-10	13	10°	20		Pour	1	Lyondell Arco+	Plate	5	
99	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
100	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
101	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
102	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
S7	Light Freezing Rain	-10	13	50/50	20		Pour	1	Kilfrost ABC-S 50/50	Plate		
S8	Light Freezing Rain	-10	13	50/50	60		Spreader	0.25	Kilfrost ABC-S 50/50	Cold Soak Box		
R31	Light Freezing Rain	-10	13	10°	20		Pour	1	UCAR ADF	Plate	5	
R32	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R33	Light Freezing Rain	-10	13	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R34	Light Freezing Rain	-10	13	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R35	Light Freezing Rain	-10	13	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
103	Light Freezing Rain	-10	25	10°	20		Pour	1	UCAR ADF	Plate	2	
104	Light Freezing Rain	-10	25	10°	20		Pour	1	Lyondell Arco+	Plate	2	
105	Light Freezing Rain	-10	25	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
106	Light Freezing Rain	-10	25	XL54	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
107	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
108	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
109	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
110	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	Lyondell Arco+	Cold Soak Box		
R36	Light Freezing Rain	-10	25	10°	20		Pour	1	UCAR ADF	Plate	2	
R37	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box		
R38	Light Freezing Rain	-10	25	10°	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		
R39	Light Freezing Rain	-10	25	10°	20		Spreader	0.5	Lyondell Arco+	Warm Cold Soak Box		
R40	Light Freezing Rain	-10	25	XL54	20		Spreader	0.5	UCAR ADF	Warm Cold Soak Box		

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ATTACHMENT E-III

NRC COLD CHAMBER TESTS – DECEMBER 2001
TEST EQUIPMENT CHECKLIST

TASK	*NRC Cold Chamber*	
	Resp.	Status
Make Hotel reservations		
Rent Van/Car		
Test Equipment		
Stand 2X3 and 2X6 + collection pans	NB	
NCAR snow machine		NO
Water for snowmaker		NO
Hand-Held Tempearture Probes X 2	NB	
Hard water for dilution (20 L)	NB	
Cups to pour 1 litre of Type I (X 12)	NB	
Precipitation rate software (Observer)	NM	
Birds eye view camera	NB	
Covers for CSW	NB	
CSW equipment	NB	
Sump Pumpa		NO
Labtop Computer x 2	NM	
Still Photo Camera	NM	
Digital Video Camera	NM	
Weigh Scales x 2	NB	
Video Camera X 2 (Surf & Snow) + Access.	NB	
Reg. Plates X 12	NB	
Data Forms for plates	NM	
Precipitation rate Data Forms	NB	
Reports + Tables (Temperature conversion, Dilution, ..)	NM	
Large Precipitation Pans x 36	NB	
Type I Fluids	NB	
Type IV Fluids	NB	
Clipboards x 3	NB	
Pencils + Space pens x 4	NB	
Paper Towels	NB	
Rubber squeegees	NB	
Plastic Refills for Fluids and funnels	NB	
Electrical Extension Cords	NB	
Lighting x 2	NB	
Clock	NB	
Storage bins for small equipment	NB	
Protective clothing (All)	NB	
Brixometer X 3	NB	
Tie wraps	NB	
Funnels	NB	
Thickness Gauges	NB	
Microscope & Accessories	NB	
Big Digital Clock	NB	
Scrapers	NB	
Cooling Unit + fluid for it		NO
Cold-Soaked Boxes 7.5 cm X 6 cm	NB	
Thermocouple Kit + Logger for CSW	NB	
Digital level	NB	
Test Procedures X 10	NM	
Fluid waste containers	NB	
Shopvac	NB	
Printer (Epson)	NM	
Detailed rate pans	NB	
Paint brushes for plate cleaning		NO
Red containers	NB	
Headsets		NO
Rate shelf	NB	
Empty bottles for samples		NO
Computers and monitors	NM	
Measurement containers X 2	NB	
Cradles	NB	
Excel software for detailed rates	NM	
Weigh Scale (1 gram)	NB	
Preweigh minerals	NB	
Big Plastic container		NO
Washers	NB	
Standard Spreaders, small holes X 2	NB	
Measuring cup kit (250/500/1000mL) X 2each	NB	
Hot Stoves X 2	NB	
Microwave	NB	
Drum craddles X 2	NB	
Drum valves X 2	NB	
Thermoses 2 X 6	NB	
Dolly	NB	
Wind Gauge	NB	
Weights X 2 sets	NB	
Distance Measurement Instrument	NM	
Boxes elbows X 4	NB	
Spray Bottles X 2	NB	
Envelopes / Time Cards / Invoices	NM	
Diskettes	NM	
Thermistor probes X 7	NB	
Loggers X 2	NB	
Logger Interface	NB	
Aluminium Speed Tape	NB	
Heat Gun	NB	
Starter Fluid	NB	

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ATTACHMENT E-IV
FLUID MIXTURES FOR TYPE I TESTS

Fluid	Brix for OAT of											
	-25°C (FP -35°C)*			-10°C (FP -20°C)			-3°C (FP -13°C)			+1°C (FP -9°C)		
	Brix	Glycol/ Litre (ml)	Water/ Litre	Brix	Glycol/ Litre (ml)	Water/ Litre (ml)	Brix	Glycol/ Litre (ml)	Water/ Litre (ml)	Brix	Glycol/ Litre (ml)	Water/ Litre (ml)
Lyondell Arco +	35.8	568	433	27.5	425	575	23.0**	352	648	20.5**	312	688
UCAR ADF	30.0	490	510	22.5	360	640	17.0	260	740	13.5	215	785
UCAR XL54	33.5	540	460	33.5	540	460	33.5	540	460	33.5	540	460

* Assumes this mixture meets aerodynamics performance.

** For the Dec. 17th to 19th testing session at NRC the brix values used (as stated by Lyondell) were 19.5 (-3°C) and 16.5 (+1°C). Subsequently, after further discussion with Lyondell, the values were changed back to the original values of 23.0 and 20.5.

M:\Groups\Cm1680 (01-02)\Procedures\Type I Protocol\NRC, Dec17\Brix(Version 2)

ATTACHMENT E-V
STAND POSITIONS

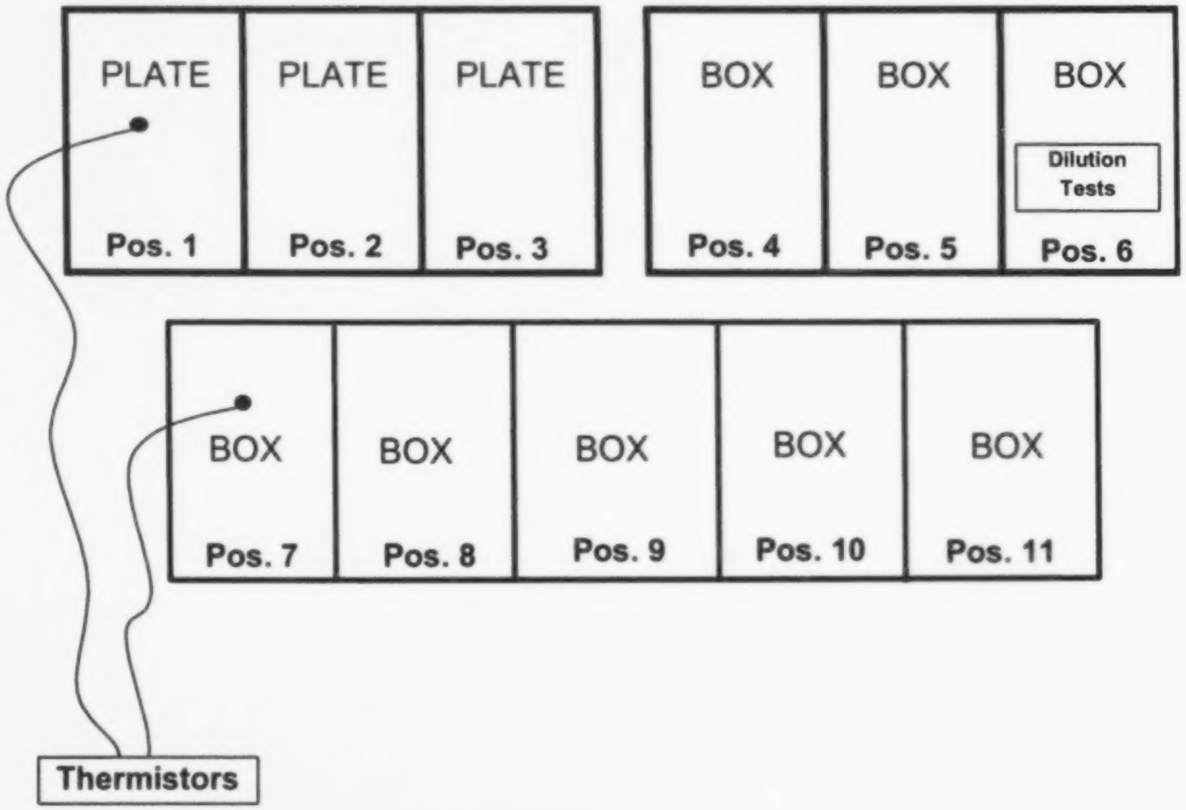
PLATE
Pos. 1
PLATE
Pos. 2
PLATE
Pos. 3
BOX
Pos. 4
BOX
Pos. 5
BOX
Dilution Tests
Pos. 6
BOX
Pos. 7
BOX
Pos. 8
BOX
Pos. 9
BOX
Pos. 10
BOX
Pos. 11
Thermistors

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RESULTS

SUMMARY OF INDOOR TYPE I TESTS USING A NEW INDOOR TEST PROTOCOL
NRC DECEMBER 2001

- ENDURANCE TIME TEST LOG
- SUMMARY TABLE OF TYPE I RESULTS
- FLUID DILUTION TEST LOG
- FLUID DILUTION VERSUS SURFACE TEMPERATURE CHARTS

SIMULATED FREEZING PRECIPITATION AT CEF-NRC (OTTAWA) TEST LOG

Seq. #	Test #	Form #	Plate Loc.	Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Fluid Name	Fluid Dilution	Surface	Application Method	Fluid Qty	Fluid Temp °	Fail Time (min)	Estimated Rate (g/dm²/hr)	Actual Rate of Precip (g/dm²/hr)	Ambient Temp (°C)	Precipitation (Type)
1	103	1	2	17-Dec-01	10:57:42	11:02:37	UCAR ADF	10°	Plate	Pour	1	20	4.9	25	26.2	-10	Light Freezing Rain
2	104	1	3	17-Dec-01	10:58:22	11:03:09	Lyondell Arco +	10°	Plate	Pour	1	20	4.8	25	26.4	-10	Light Freezing Rain
3	105	1	4	17-Dec-01	10:59:40	11:06:40	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	7.0	25	26.6	-10	Light Freezing Rain
4	106	1	5	17-Dec-01	11:01:10	11:07:09	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	6.0	25	26.7	-10	Light Freezing Rain
5	107	1	8	17-Dec-01	11:02:50	11:10:24	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	7.6	25	25.7	-10	Light Freezing Rain
6	108	1	9	17-Dec-01	11:04:39	11:11:00	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	6.4	25	25.8	-10	Light Freezing Rain
7	109	1	10	17-Dec-01	11:05:37	11:12:00	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	6.4	25	26.6	-10	Light Freezing Rain
8	110	1	11	17-Dec-01	11:06:37	11:13:06	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	6.5	25	26.3	-10	Light Freezing Rain
9	97	2	2	17-Dec-01	12:53:10	12:58:41	UCAR ADF	10°	Plate	Pour	1	20	5.5	13	12.8	-10	Light Freezing Rain
10	98	2	3	17-Dec-01	12:54:06	12:59:58	Lyondell Arco +	10°	Plate	Pour	1	20	5.9	13	13.3	-10	Light Freezing Rain
11	99	2	4	17-Dec-01	12:56:43	13:02:20	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	5.6	13	13.4	-10	Light Freezing Rain
12	100	2	5	17-Dec-01	12:58:13	13:03:43	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	5.5	13	13.5	-10	Light Freezing Rain
13	101	2	8	17-Dec-01	12:59:51	13:05:30	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	5.7	13	12.9	-10	Light Freezing Rain
14	102	2	9	17-Dec-01	13:01:20	13:06:29	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	5.2	13	12.9	-10	Light Freezing Rain
15	S8	2	10	17-Dec-01	13:04:36	13:20:00	Kilfrost ABC-S 50/50	50/50	Cold Soak Box	Spreader	0.25	60	15.4	13	13.1	-10	Light Freezing Rain
16	S7	2	2	17-Dec-01	13:08:31	13:21:20	Kilfrost ABC-S 50/50	50/50	Plate	Pour	1	20	12.8	13	12.8	-10	Light Freezing Rain
17	35	3	1	17-Dec-01	16:11:25	16:17:30	UCAR ADF	10°	Plate	Pour	1	20	6.1	13	12.2	-10	Freezing Drizzle
18	36	3	1	17-Dec-01	16:20:05	16:26:01	Lyondell Arco +	10°	Plate	Pour	1	20	5.9	13	12.2	-10	Freezing Drizzle
19	38	3	8	17-Dec-01	16:22:14	16:27:40	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	5.4	13	12.1	-10	Freezing Drizzle
20	39	3	8	17-Dec-01	16:12:44	16:18:52	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	6.1	13	12.1	-10	Freezing Drizzle
21	40	3	9	17-Dec-01	16:13:48	16:20:19	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	6.5	13	11.7	-10	Freezing Drizzle
22	S4	3	10	17-Dec-01	16:15:43	16:33:52	Kilfrost ABC-S 50/50	50/50	Cold Soak Box	Spreader	0.25	60	18.2	13	11.7	-10	Freezing Drizzle
23	37	3	11	17-Dec-01	16:17:02	16:22:27	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	5.4	13	13.1	-10	Freezing Drizzle
24	S3	3	1	17-Dec-01	16:27:29	16:41:06	Kilfrost ABC-S 50/50	50/50	Plate	Pour	1	20	13.6	13	12.2	-10	Freezing Drizzle
25	27	4	2	17-Dec-01	17:48:39	17:56:58	UCAR ADF	10°	Plate	Pour	1	20	8.3	5	5.4	-10	Freezing Drizzle
26	28	4	3	17-Dec-01	17:50:13	17:58:28	Lyondell Arco +	10°	Plate	Pour	1	20	8.3	5	5.1	-10	Freezing Drizzle
27	29	4	4	17-Dec-01	17:51:22	18:01:28	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	10.1	5	5.4	-10	Freezing Drizzle
28	30	4	5	17-Dec-01	17:52:26	18:01:42	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	9.3	5	5.8	-10	Freezing Drizzle
29	31	4	8	17-Dec-01	17:53:38	18:02:18	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	8.7	5	5.1	-10	Freezing Drizzle
30	32	4	9	17-Dec-01	17:55:02	18:03:34	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	8.5	5	5.4	-10	Freezing Drizzle
31	33	4	10	17-Dec-01	17:58:07	18:07:36	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	9.5	5	5.6	-10	Freezing Drizzle

SIMULATED FREEZING PRECIPITATION AT CEF-NRC (OTTAWA) TEST LOG

Seq. #	Test #	Form #	Plate Loc.	Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Fluid Name	Fluid Dilution	Surface	Application Method	Fluid Qty	Fluid Temp °C	Fail Time (min)	Estimated Rate (g/dm²/hr)	Actual Rate of Precip (g/dm²/hr)	Ambient Temp (°C)	Precipitation (Type)
32	34	4	11	17-Dec-01	17:59:51	18:08:11	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	8.3	5	5.8	-10	Freezing Drizzle
33	13	5	2	17-Dec-01	20:21:49	20:35:26	UCAR ADF	10°	Plate	Pour	1	20	13.6	5	4.7	-3	Freezing Drizzle
34	14	5	3	17-Dec-01	20:22:46	20:36:20	Lyondell Arco +	10°	Plate	Pour	1	20	13.6	5	4.5	-3	Freezing Drizzle
35	15	5	4	17-Dec-01	20:24:03	20:52:25	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	28.4	5	5.4	-3	Freezing Drizzle
36	16	5	7	17-Dec-01	20:26:05	20:45:30	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	19.4	5	4.8	-3	Freezing Drizzle
37	17	5	8	17-Dec-01	20:27:33	20:50:53	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	23.3	5	5.1	-3	Freezing Drizzle
38	18	5	9	17-Dec-01	20:28:45	20:49:43	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	21.0	5	5.3	-3	Freezing Drizzle
39	19	5	1	17-Dec-01	20:35:06	20:59:43	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	24.6	5	4.3	-3	Freezing Drizzle
40	20	5	3	17-Dec-01	20:38:48	21:00:42	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	21.9	5	4.5	-3	Freezing Drizzle
41	4	6	9	18-Dec-01	9:36:57	9:41:43	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	4.8	5	5.2	+1	Cold Soak
42	2	6	7	18-Dec-01	9:06:16	9:12:32	Lyondell Arco +	10°	Cold Soak Box	Pour	1	20	6.3	5	5.1	+1	Cold Soak
43	1	6	4	18-Dec-01	9:08:10	9:13:37	UCAR ADF	10°	Cold Soak Box	Pour	1	20	5.5	5	5.1	+1	Cold Soak
44	3	6	4	18-Dec-01	9:16:32	9:22:10	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	5.6	5	5.1	+1	Cold Soak
45	5	6	7	18-Dec-01	9:18:25	9:23:28	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	5.1	5	5.1	+1	Cold Soak
46	6	6	9	18-Dec-01	9:26:15	9:32:09	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	5.9	5	5.2	+1	Cold Soak
47	7	7	3	18-Dec-01	11:04:18	11:06:40	UCAR ADF	10°	Cold Soak Box	Pour	1	20	2.4	75	77.4	+1	Cold Soak
48	8	7	10	18-Dec-01	11:06:47	11:08:40	Lyondell Arco +	10°	Cold Soak Box	Pour	1	20	1.9	75	73.8	+1	Cold Soak
49	9	7	10	18-Dec-01	11:11:02	11:12:32	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	1.5	75	73.8	+1	Cold Soak
50	10	7	1	18-Dec-01	11:00:03	11:02:09	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	2.1	75	75.0	+1	Cold Soak
51	12	7	3	18-Dec-01	11:14:06	11:16:32	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	2.4	75	77.4	+1	Cold Soak
52	11	7	10	18-Dec-01	11:16:48	11:18:21	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	1.6	75	73.8	+1	Cold Soak
53	83	8	1	18-Dec-01	12:37:15	12:51:19	UCAR ADF	10°	Plate	Pour	1	20	14.1	13	12.5	-3	Light Freezing Rain
54	84	8	2	18-Dec-01	12:37:58	12:49:45	Lyondell Arco +	10°	Plate	Pour	1	20	11.8	13	12.6	-3	Light Freezing Rain
55	85	8	5	18-Dec-01	12:40:31	13:02:27	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	21.9	13	13.1	-3	Light Freezing Rain
56	86	8	7	18-Dec-01	12:42:30	13:08:01	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	25.5	13	12.5	-3	Light Freezing Rain
57	87	8	6	18-Dec-01	12:43:39	13:02:48	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	19.2	13	13.5	-3	Light Freezing Rain
58	88	8	8	18-Dec-01	12:44:49	13:08:59	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	24.2	13	13.1	-3	Light Freezing Rain
59	S5	8	3	18-Dec-01	12:39:17	12:58:22	Kilfrost ABC-S 50/50	50/50	Plate	Pour	1	20	19.1	13	13.0	-3	Light Freezing Rain
60	S6	8	9	18-Dec-01	12:46:35	13:20:53	Kilfrost ABC-S 50/50	50/50	Cold Soak Box	Spreader	0.25	60	34.3	13	12.9	-3	Light Freezing Rain
61	89	9	1	18-Dec-01	14:12:27	14:25:05	UCAR ADF	10°	Plate	Pour	1	20	12.6	25	22.4	-3	Light Freezing Rain
62	90	9	2	18-Dec-01	14:13:51	14:25:10	Lyondell Arco +	10°	Plate	Pour	1	20	11.3	25	22.2	-3	Light Freezing Rain
63	91	9	4	18-Dec-01	14:15:37	14:39:00	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	23.4	25	22.1	-3	Light Freezing Rain

SIMULATED FREEZING PRECIPITATION AT CEF-NRC (OTTAWA) TEST LOG

Seq. #	Test #	Form #	Plate Loc.	Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Fluid Name	Fluid Dilution	Surface	Application Method	Fluid Qty	Fluid Temp ©	Fail Time (min)	Estimated Rate (g/dm^2/hr)	Actual Rate of Precip (g/dm^2/hr)	Ambient Temp (°C)	Precipitation (Type)
64	92	9	5	18-Dec-01	14:16:51	14:29:58	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	13.1	25	22.8	-3	Light Freezing Rain
65	93	9	7	18-Dec-01	14:19:35	14:47:23	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	27.8	25	22.9	-3	Light Freezing Rain
66	94	9	6	18-Dec-01	14:17:55	14:37:24	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	19.5	25	23.0	-3	Light Freezing Rain
67	95	9	9	18-Dec-01	14:20:48	14:35:33	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	14.8	25	22.4	-3	Light Freezing Rain
68	96	9	10	18-Dec-01	14:21:40	14:45:53	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	24.2	25	22.2	-3	Light Freezing Rain
69	21	10	1	18-Dec-01	16:28:14	16:42:15	UCAR ADF	10°	Plate	Pour	1	20	14.0	13	12.2	-3	Freezing Drizzle
70	22	10	3	18-Dec-01	16:35:18	16:49:40	Lyondell Arco +	10°	Plate	Pour	1	20	14.4	13	11.7	-3	Freezing Drizzle
71	23	10	1	18-Dec-01	16:48:40	17:15:56	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	27.3	13	12.2	-3	Freezing Drizzle
72	24	10	5	18-Dec-01	16:37:06	16:57:15	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	20.2	13	12.9	-3	Freezing Drizzle
73	25	10	5	18-Dec-01	16:11:42	16:35:47	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	24.1	13	12.9	-3	Freezing Drizzle
74	26	10	6	18-Dec-01	16:40:58	16:55:08	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	14.2	13	13.3	-3	Freezing Drizzle
75	S1	10	3	18-Dec-01	16:09:05	16:32:10	Kilfrost ABC-S 50/50	50/50	Plate	Pour	1	20	23.1	13	11.7	-3	Freezing Drizzle
76	S2	10	4	18-Dec-01	16:10:35	16:48:40	Kilfrost ABC-S 50/50	50/50	Cold Soak Box	Spreader	0.25	60	38.1	13	12.1	-3	Freezing Drizzle
77	49	11	4	18-Dec-01	19:18:10	19:30:16	UCAR ADF	10°	Plate	Pour	1	20	12.1	5	5.1	-3	Freezing Fog
78	50	11	6	18-Dec-01	19:18:50	19:31:29	Lyondell Arco +	10°	Plate	Pour	1	20	12.7	5	4.8	-3	Freezing Fog
79	51	11	9	18-Dec-01	19:13:00	19:34:08	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	21.1	5	5.2	-3	Freezing Fog
80	52	11	11	18-Dec-01	19:14:23	19:31:26	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	17.1	5	5.2	-3	Freezing Fog
81	53	11	8	18-Dec-01	19:15:44	19:32:45	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	17.0	5	5.2	-3	Freezing Fog
82	54	11	10	18-Dec-01	19:20:36	19:36:40	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	16.1	5	5.4	-3	Freezing Fog
83	41	12	3	18-Dec-01	20:45:53	21:02:22	UCAR ADF	10°	Plate	Pour	1	20	16.5	2	2.0	-3	Freezing Fog
84	42	12	2	18-Dec-01	20:44:11	21:04:41	Lyondell Arco +	10°	Plate	Pour	1	20	20.5	2	1.8	-3	Freezing Fog
85	43	12	6	18-Dec-01	20:42:39	21:07:20	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	24.7	2	2.1	-3	Freezing Fog
86	44	12	5	18-Dec-01	20:41:31	21:06:04	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	24.6	2	2.3	-3	Freezing Fog
87	45	12	4	18-Dec-01	20:40:20	21:02:49	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	22.5	2	2.2	-3	Freezing Fog
88	46	12	9	18-Dec-01	20:37:05	20:58:12	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	21.1	2	1.9	-3	Freezing Fog
89	47	12	10	18-Dec-01	20:36:06	21:00:21	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	24.3	2	1.9	-3	Freezing Fog
90	48	12	11	18-Dec-01	20:34:58	20:59:29	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	24.5	2	2.0	-3	Freezing Fog
91	69	13	3	19-Dec-01	10:01:54	10:11:42	UCAR ADF	10°	Plate	Pour	1	20	9.8	2	1.8	-25	Freezing Fog
92	70	13	3	19-Dec-01	10:17:09	10:30:32	Lyondell Arco +	10°	Plate	Pour	1	20	13.4	2	1.8	-25	Freezing Fog
93	71	13	11	19-Dec-01	10:32:27	10:44:07	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	11.7	2	2.3	-25	Freezing Fog
94	72	13	3	19-Dec-01	10:33:48	10:45:57	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	12.2	2	1.8	-25	Freezing Fog
95	73	13	11	19-Dec-01	10:03:40	10:12:48	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	9.1	2	2.3	-25	Freezing Fog

SIMULATED FREEZING PRECIPITATION AT CEF-NRC (OTTAWA) TEST LOG

Seq. #	Test #	Form #	Plate Loc.	Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Fluid Name	Fluid Dilution	Surface	Application Method	Fluid Qty	Fluid Temp °	Fail Time (min)	Estimated Rate (g/dm²/hr)	Actual Rate of Precip (g/dm²/hr)	Ambient Temp (°C)	Precipitation (Type)
96	74	13	11	19-Dec-01	10:47:54	10:59:56	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	12.0	2	2.3	-25	Freezing Fog
97	75	13	11	19-Dec-01	10:18:00	10:29:59	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	12.0	2	2.3	-25	Freezing Fog
98	76	13	3	19-Dec-01	10:49:12	10:58:25	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	9.2	2	1.8	-25	Freezing Fog
99	77	14	6	19-Dec-01	11:05:29	11:11:43	UCAR ADF	10°	Plate	Pour	1	20	6.2	5	5.2	-25	Freezing Fog
100	78	14	6	19-Dec-01	11:14:10	11:22:56	Lyondell Arco +	10°	Plate	Pour	1	20	8.8	5	5.2	-25	Freezing Fog
101	79	14	6	19-Dec-01	11:25:50	11:30:00	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	4.2	5	5.2	-25	Freezing Fog
102	80	14	6	19-Dec-01	10:07:46	10:14:00	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	6.2	5	4.9	-25	Freezing Fog
103	81	14	6	19-Dec-01	11:34:54	11:42:18	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	7.4	5	5.2	-25	Freezing Fog
104	82	14	6	19-Dec-01	11:46:17	11:54:48	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	8.5	5	5.2	-25	Freezing Fog
105	63	15	4	19-Dec-01	14:52:55	15:00:42	UCAR ADF	10°	Plate	Pour	1	20	7.8	5	4.5	-10	Freezing Fog
106	64	15	6	19-Dec-01	14:43:53	14:52:06	Lyondell Arco +	10°	Plate	Pour	1	20	8.2	5	4.7	-10	Freezing Fog
107	65	15	5	19-Dec-01	14:54:02	15:02:33	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	8.5	5	4.5	-10	Freezing Fog
108	66	15	6	19-Dec-01	14:54:49	15:03:30	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	8.7	5	4.7	-10	Freezing Fog
109	67	15	5	19-Dec-01	14:42:19	14:51:18	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	9.0	5	4.5	-10	Freezing Fog
110	68	15	4	19-Dec-01	14:40:15	14:49:30	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	9.3	5	4.5	-10	Freezing Fog
111	55	16	1	19-Dec-01	16:06:02	16:17:25	UCAR ADF	10°	Plate	Pour	1	20	11.4	2	2.1	-10	Freezing Fog
112	56	16	1	19-Dec-01	16:19:06	16:30:10	Lyondell Arco +	10°	Plate	Pour	1	20	11.1	2	2.1	-10	Freezing Fog
113	57	16	10	19-Dec-01	16:10:08	16:23:30	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	13.4	2	2.4	-10	Freezing Fog
114	58	16	11	19-Dec-01	16:10:48	16:25:30	UCAR ADF	XL54	Cold Soak Box	Spreader	0.25	60	14.7	2	2.2	-10	Freezing Fog
115	59	16	7	19-Dec-01	16:07:47	16:21:21	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	13.6	2	2.0	-10	Freezing Fog
116	60	16	8	19-Dec-01	16:08:58	16:20:29	UCAR ADF	10°	Cold Soak Box	Spreader	0.25	60	11.5	2	1.9	-10	Freezing Fog
117	61	16	9	19-Dec-01	16:17:19	16:28:13	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	10.9	2	2.2	-10	Freezing Fog
118	62	16	8	19-Dec-01	16:21:39	16:33:30	Lyondell Arco +	10°	Cold Soak Box	Spreader	0.25	60	11.9	2	1.9	-10	Freezing Fog

Table E-1

Summary of Type I Results from December 17, 2001 Test

Surface	OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
	°C	°F	FROST	FREEZING FOG	SNOW ①	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
HOT	above 0	above 32	**45.0**	**12 - 30**	**7 - 12**	**5 - 8**	**2 - 5**	**2 - 5**	**CAUTION** **No holdover time guidelines exist**
PLT. AVG E (MC)*								*E: 2 - 6*	
PLATE E (AA)*								*E: 2.4 - 5.5*	
BOX E								*E: 1.5 - 4.8* *E: 2.1 - 5.6*	
PLT. AVG P (MC)*								*P: 2 - 9*	
PLATE P (AA)*								*P: 1.9 - 6.3*	
BOX P								*P: 2.4 - 5.1* *P: 1.6 - 5.9*	
XL 54									
HOT	-3	27	**45.0**	**6 - 11**	**3 - 6**	**5 - 8**	**2 - 5**		
PLT. AVG E (MC)									
PLATE E (AA)				*E: 12.1 - 16.5*		*E: 14.0 - 13.6*	*E: 12.6 - 14.1*		
BOX E				*E: 21.1 - 22.5* *E: 17.1 - 21.1*		*E: 27.3 - 23.3* *E: 20.2 - 21*	*E: 27.8 - 21.9* *E: 19.5 - 25.5*		
PLT. AVG P (MC)									
PLATE P (AA)				*P: 12.7 - 20.5*		*P: 14.4 - 13.6*	*P: 11.3 - 11.8*		
BOX P				*P: 17.0 - 24.3* *P: 16.1 - 24.5*		*P: 24.1 - 24.6* *P: 14.2 - 21.9*	*P: 14.8 - 19.2* *P: 24.2 - 24.2*		
XL 54				*E: 24.7* *E: 24.6*		*E: 28.4* *E: 19.4*	*E: 23.4* *E: 13.1*		
HOT	0 to -10	32 to 14	**45.0**	**6 - 11**	**3 - 6**	**5 - 8**	**2 - 5**		
PLT. AVG E (MC)				*E: 6 - 11*		*E: 6 - 8*	*E: 4 - 5*		
PLATE E (AA)				*E: 7.8 - 11.4*		*E: 6.1 - 8.3*	*E: 4.9 - 5.5*		
BOX E				*E: 8.5 - 13.6* *E: 8.7 - 11.5*		*E: 5.4 - 8.7* *E: 5.4 - 8.5*	*E: 7.6 - 5.6* *E: 6.4 - 5.5*		
PLT. AVG P (MC)				*P: 8 - 12*		*P: 6 - 7*	*P: 4 - 5*		
PLATE P (AA)				*P: 8.2 - 11.1*		*P: 5.9 - 8.3*	*P: 4.8 - 5.9*		
BOX P				*P: 9.0 - 10.9* *P: 9.3 - 11.9*		*P: 6.1 - 9.5* *P: 6.5 - 8.3*	*P: 6.4 - 5.7* *P: 6.5 - 5.2*		
XL 54				*E: 13.4* *E: 14.7*		*E: 10.1* *E: 9.3*	*E: 7* *E: 6*		
HOT	-10 to -25	14 to -13	**45.0**	**6 - 9**	**2 - 4**				
PLT. AVG E (MC)				*E: 5 - 11*					
PLATE E (AA)				*E: 6.2 - 9.8*					
BOX E				*E: 4.2 - 9.1* *E: 6.2 - 12.0*					
PLT. AVG P (MC)				*P: 7 - 13*					
PLATE P (AA)				*P: 8.8 - 13.4*					
BOX P				*P: 7.4 - 12.0* *P: 8.5 - 9.2*					
XL 54				*E: 11.7* *E: 12.2*					

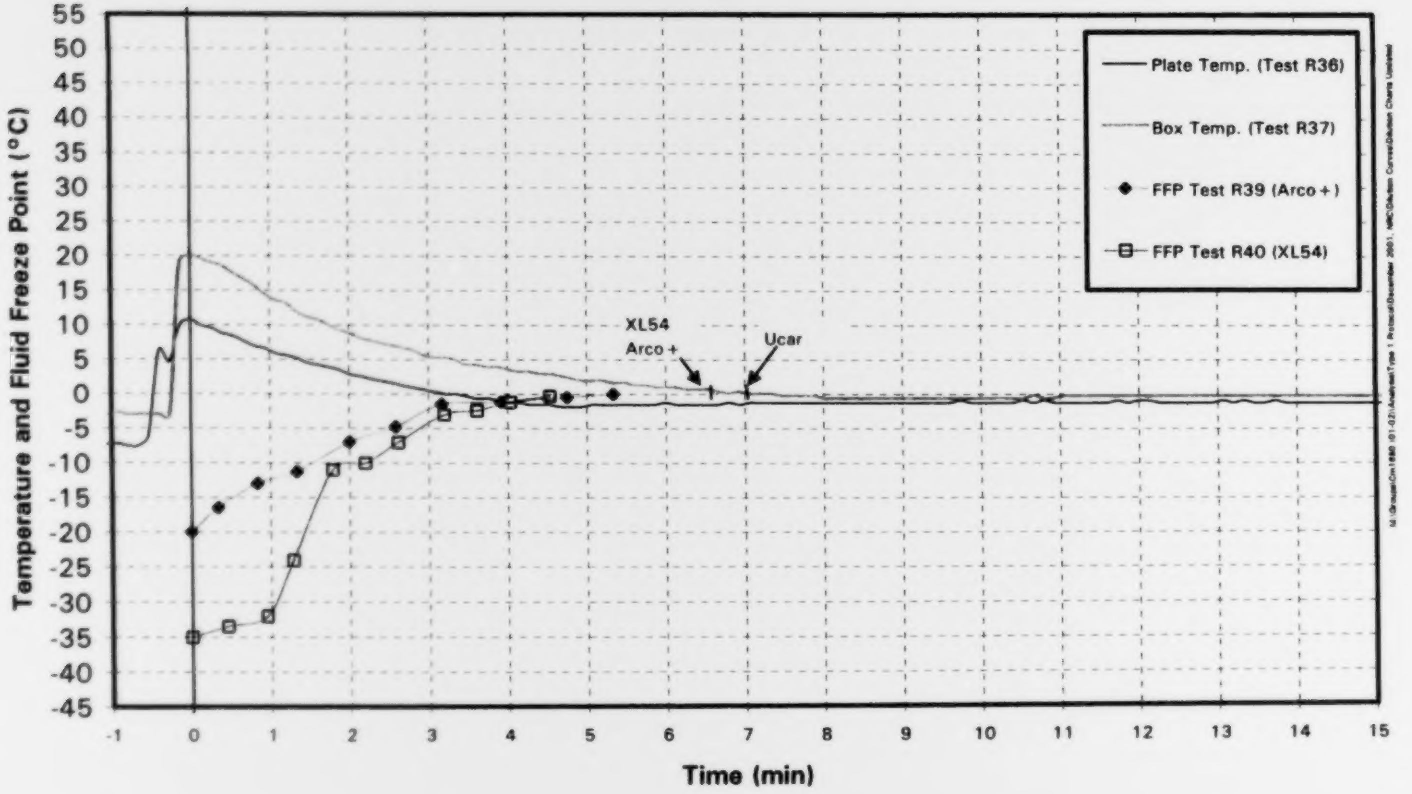
E - Ethylene Fluid (UCAR ADF)

P - Propylene Fluid (Lyondell Arco+)

*** - Tests had been run using boxes and the old method of fluid application (Pour at 20°C)**

FLUID DILUTION TEST LOG

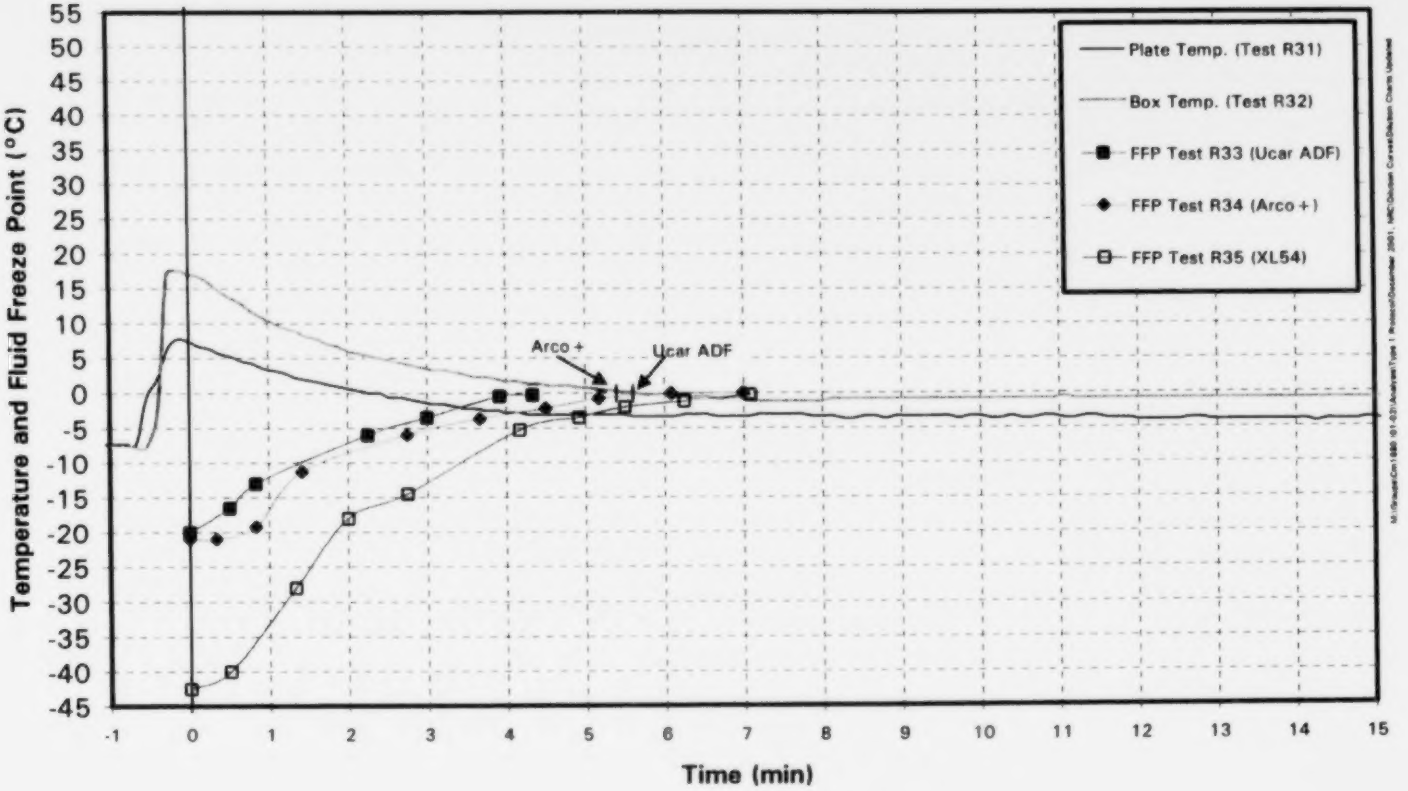
Test #	Precipitation Type	Test Temp. [°C]	Precipitation Rate [g/dm^2/h]	Dilution [%] 10° Buffer XL54 Premix	Fluid Temp. [°C]	Application Method	Quantity [L]	Glycol Type	Surface
R1	Freezing Drizzle	-3	5	10°	20	Pour	1	UCAR ADF	Plate
R2	Freezing Drizzle	-3	5	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R3	Freezing Drizzle	-3	5	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R4	Freezing Drizzle	-3	5	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R5	Freezing Drizzle	-3	5	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R6	Freezing Drizzle	-3	13	10°	20	Pour	1	UCAR ADF	Plate
R7	Freezing Drizzle	-3	13	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R8	Freezing Drizzle	-3	13	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R9	Freezing Drizzle	-3	13	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R10	Freezing Drizzle	-3	13	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R11	Freezing Drizzle	-10	5	10°	20	Pour	1	UCAR ADF	Plate
R12	Freezing Drizzle	-10	5	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R13	Freezing Drizzle	-10	5	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R14	Freezing Drizzle	-10	5	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R15	Freezing Drizzle	-10	5	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R16	Freezing Drizzle	-10	13	10°	20	Pour	1	UCAR ADF	Plate
R17	Freezing Drizzle	-10	13	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R18	Freezing Drizzle	-10	13	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R19	Freezing Drizzle	-10	13	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R20	Freezing Drizzle	-10	13	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R21	Light Freezing Rain	-3	13	10°	20	Pour	1	UCAR ADF	Plate
R22	Light Freezing Rain	-3	13	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R23	Light Freezing Rain	-3	13	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R24	Light Freezing Rain	-3	13	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R25	Light Freezing Rain	-3	13	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R26	Light Freezing Rain	-3	25	10°	20	Pour	1	UCAR ADF	Plate
R27	Light Freezing Rain	-3	25	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R28	Light Freezing Rain	-3	25	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R29	Light Freezing Rain	-3	25	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R30	Light Freezing Rain	-3	25	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R31	Light Freezing Rain	-10	13	10°	20	Pour	1	UCAR ADF	Plate
R32	Light Freezing Rain	-10	13	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R33	Light Freezing Rain	-10	13	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R34	Light Freezing Rain	-10	13	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R35	Light Freezing Rain	-10	13	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R36	Light Freezing Rain	-10	25	10°	20	Pour	1	UCAR ADF	Plate
R37	Light Freezing Rain	-10	25	10°	60	Spreader	0.25	UCAR ADF	Cold Soak Box
R38	Light Freezing Rain	-10	25	10°	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box
R39	Light Freezing Rain	-10	25	10°	20	Spreader	0.5	Lyondell Arco +	Warm Cold Soak Box
R40	Light Freezing Rain	-10	25	XL54	20	Spreader	0.5	UCAR ADF	Warm Cold Soak Box

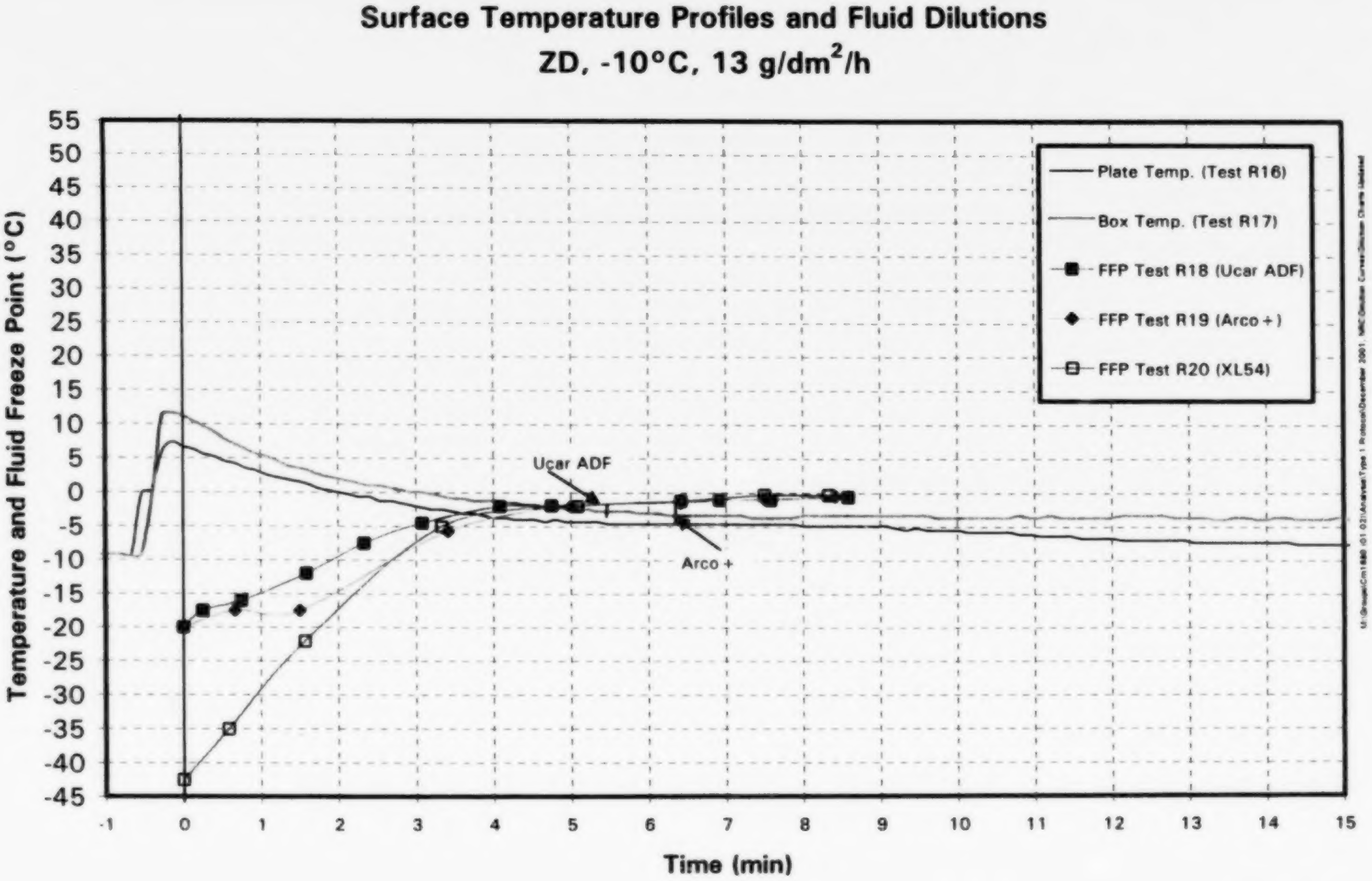


Surface Temperature Profiles and Fluid Dilutions

ZR, -10°C, 25 g/dm²/h

Surface Temperature Profiles and Fluid Dilutions
ZR, -10°C, 13 g/dm^2/h



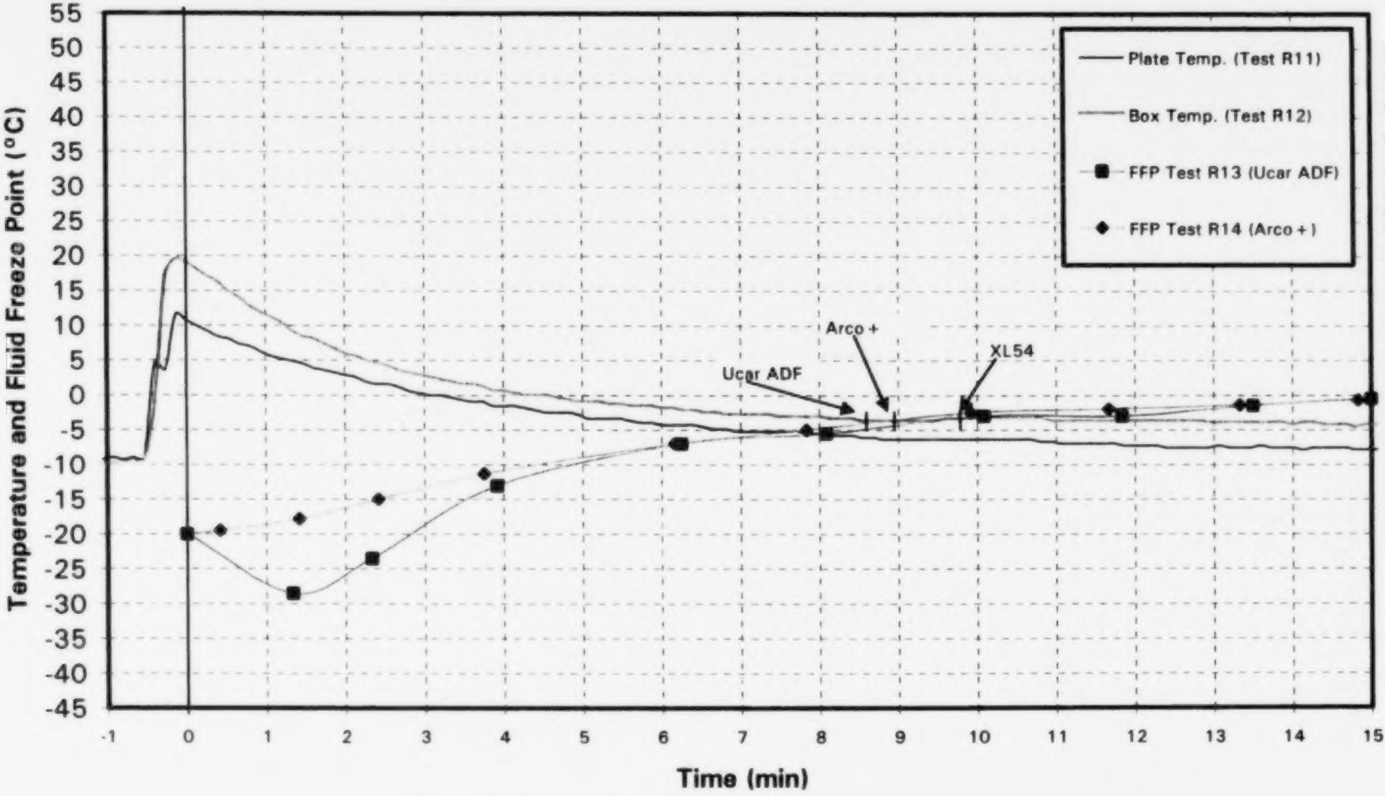


Surface Temperature Profiles and Fluid Dilutions

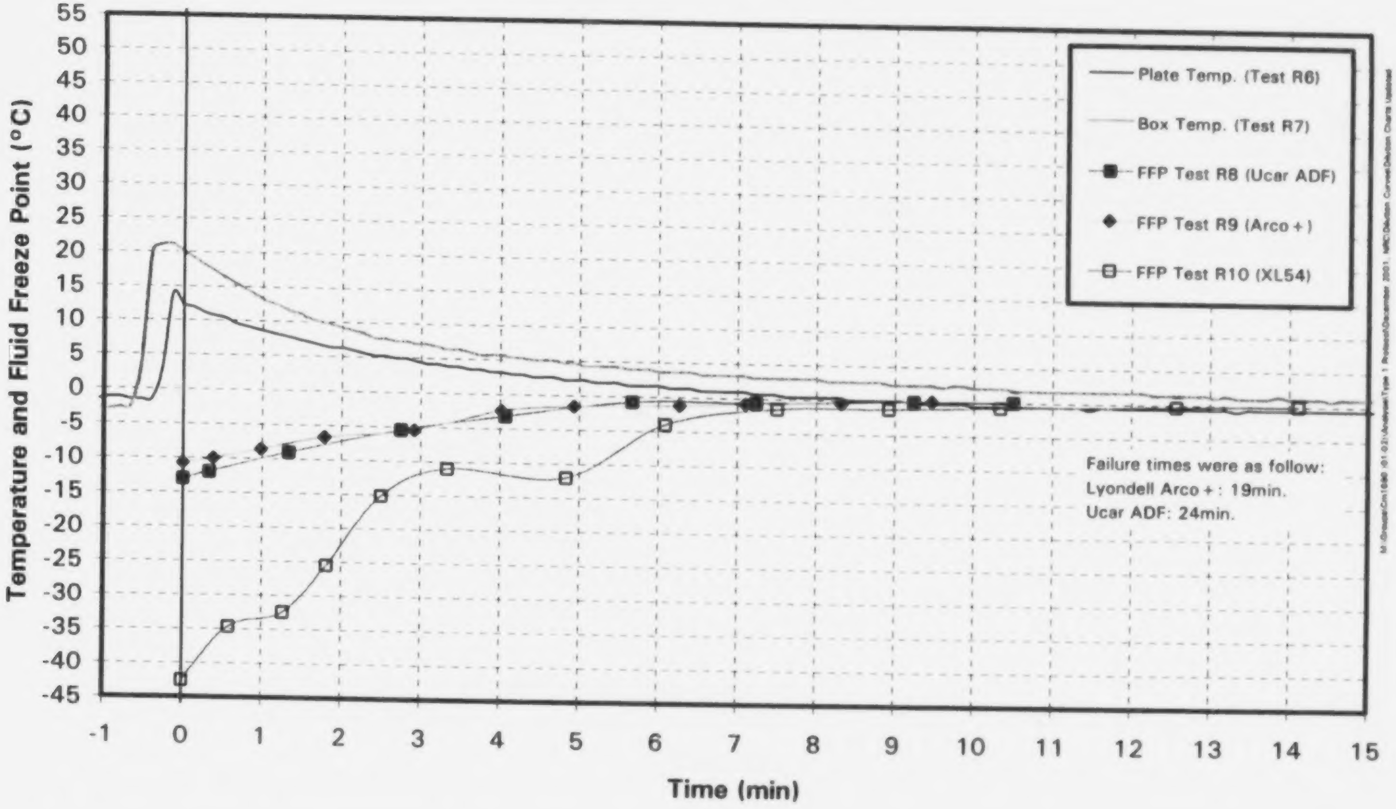
ZD, -10°C, 13 g/dm²/h

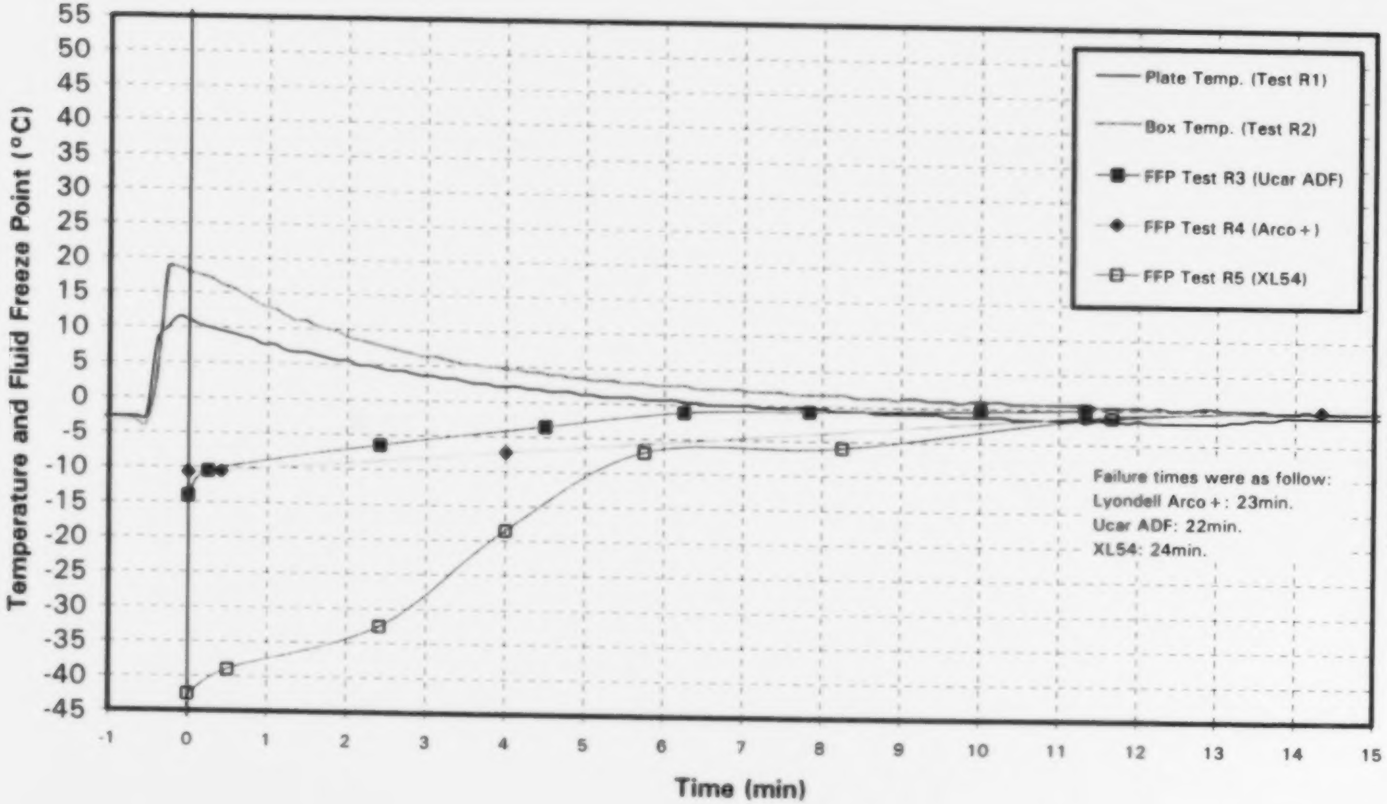
Surface Temperature Profiles and Fluid Dilutions

ZD, -10°C, 5 g/dm^2/h



Surface Temperature Profiles and Fluid Dilutions
ZD, -3°C, 13 g/dm²/h





Surface Temperature Profiles and Fluid Dilutions

ZD, -3°C, 5 g/dm²/h

Failure times were as follow:
Lyondell Arco+: 23min.
Ucar ADF: 22min.
XL54: 24min.

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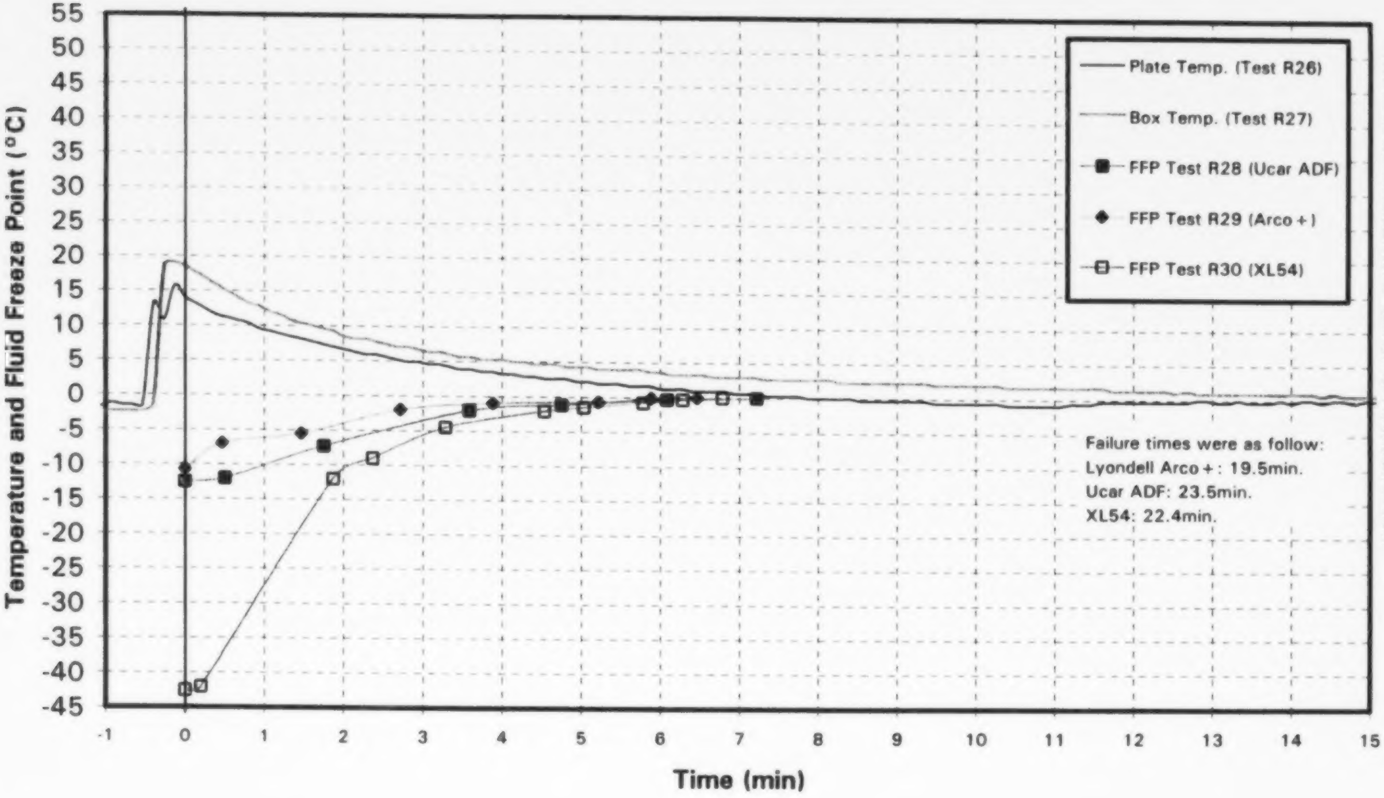
Surface Temperature Profiles and Fluid Dilutions
ZR, -3°C, 25 g/dm²/h



Failure times were as follow:
Lyondell Arco+: 19.5min.
Ucar ADF: 23.5min.
XL54: 22.4min.

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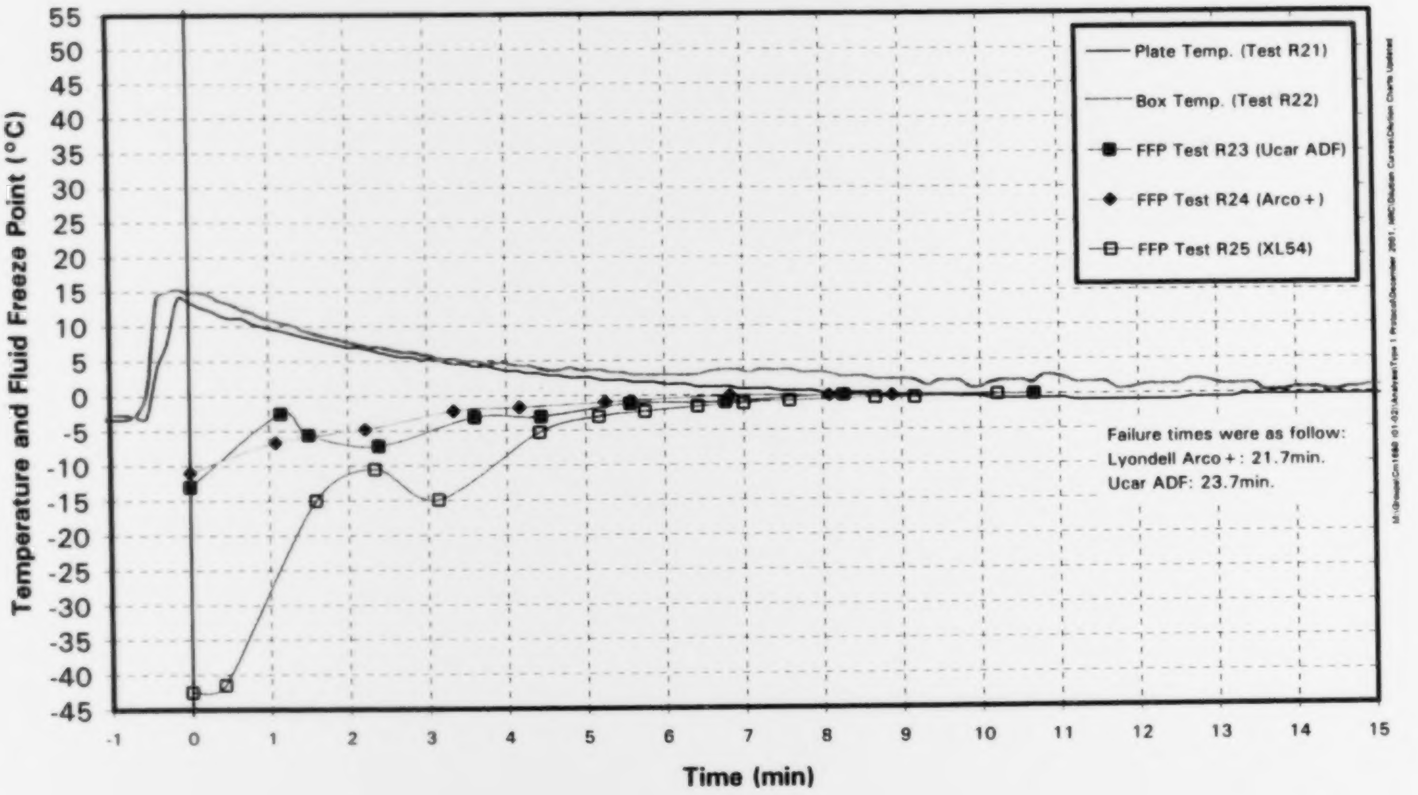
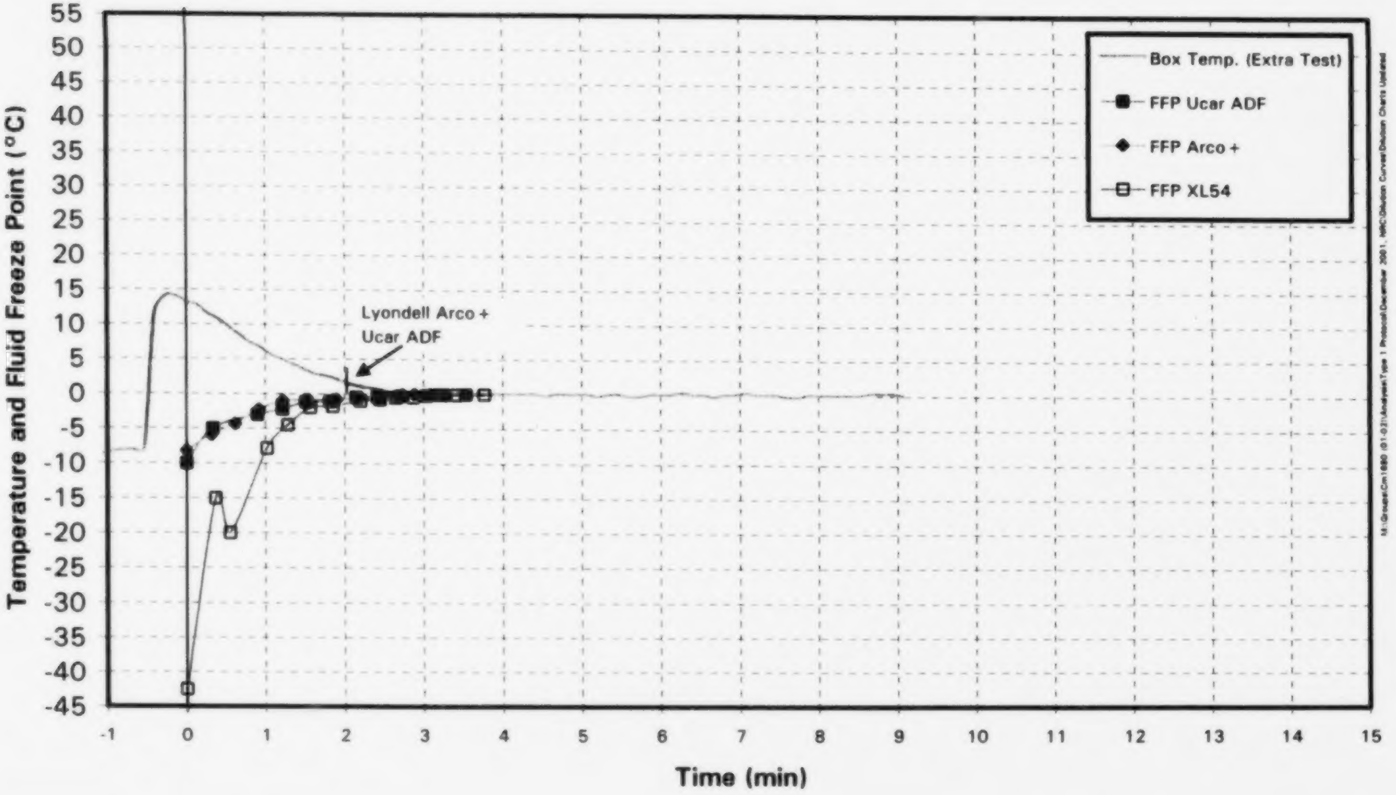
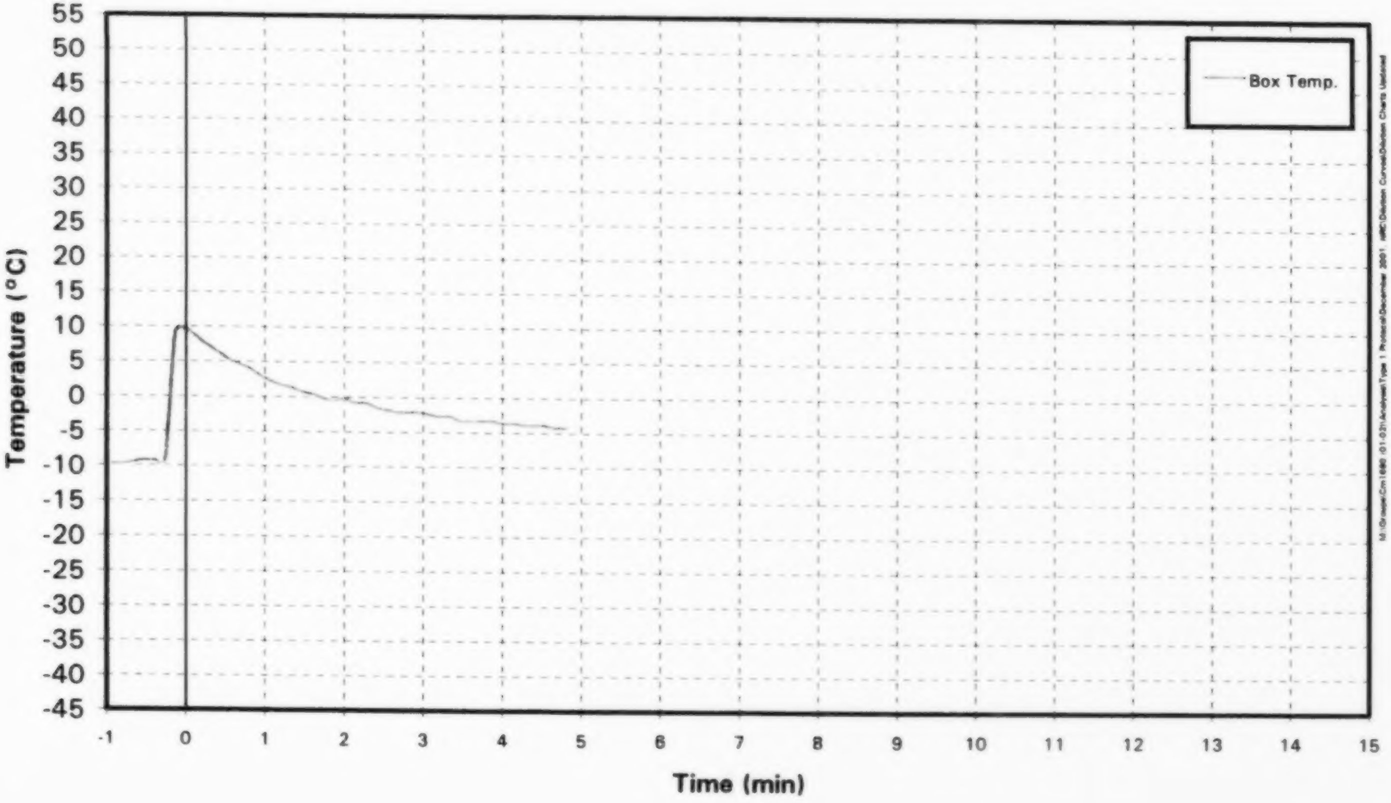
Surface Temperature Profiles and Fluid Dilutions
ZR, -3°C, 13 g/dm²/h



Failure times were as follow:
Lyondell Arco+: 21.7min.
Ucar ADF: 23.7min.

Surface Temperature Profile and Fluid Dilutions
ROCSB, + 1°C, 75 g/dm²/h

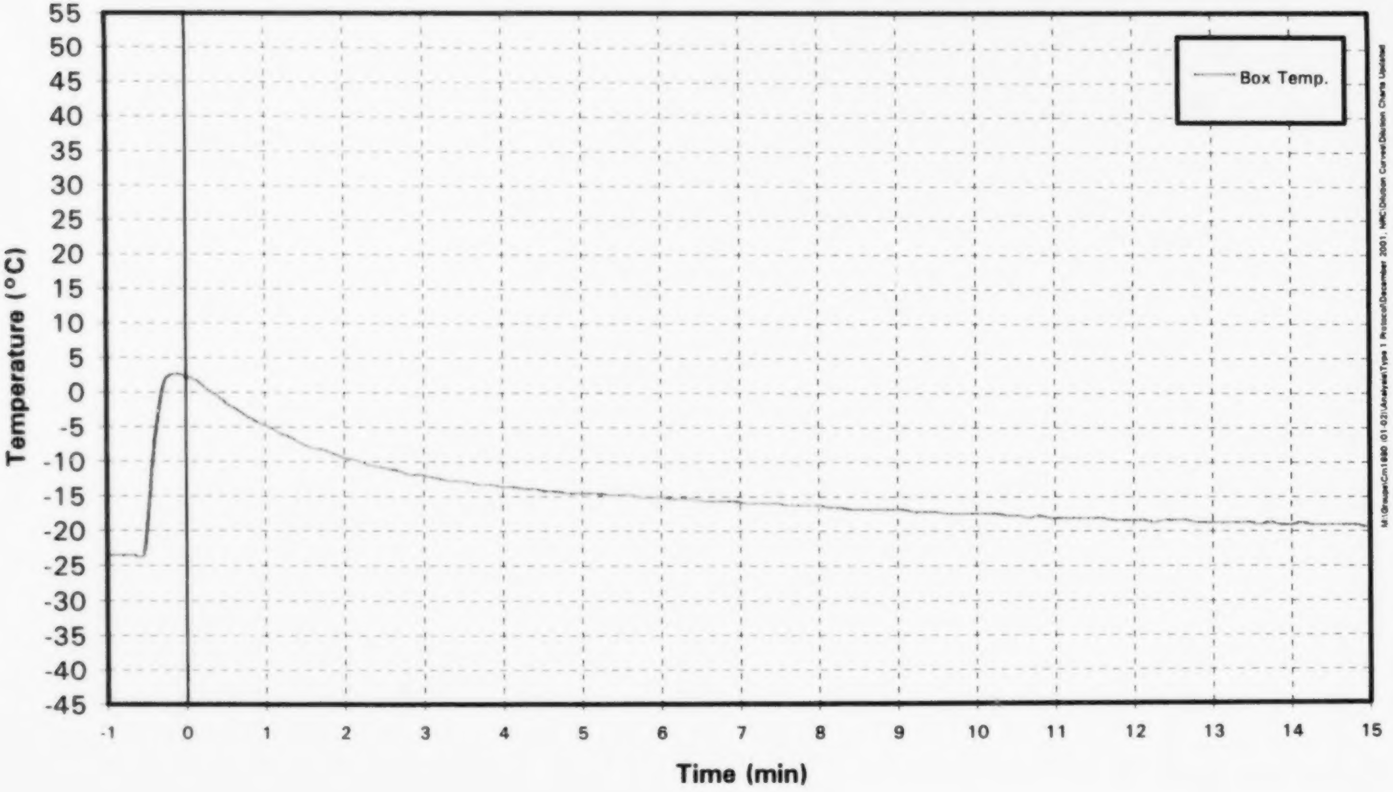




Surface Temperature Profile
ROCSB, +1°C, 5 g/dm²/h

Surface Temperature Profile

ZF, -25°C, 5 g/dm²/h



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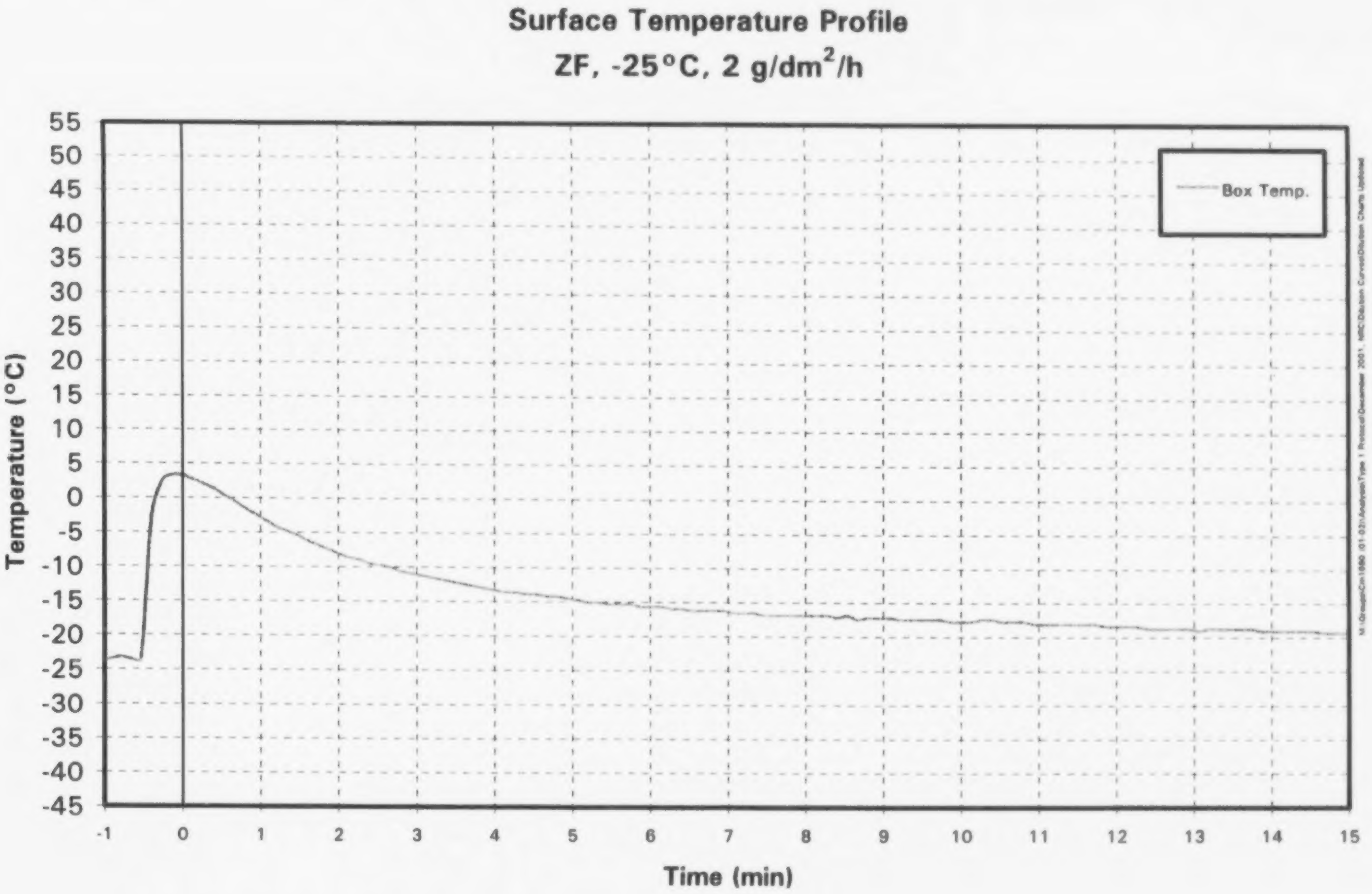
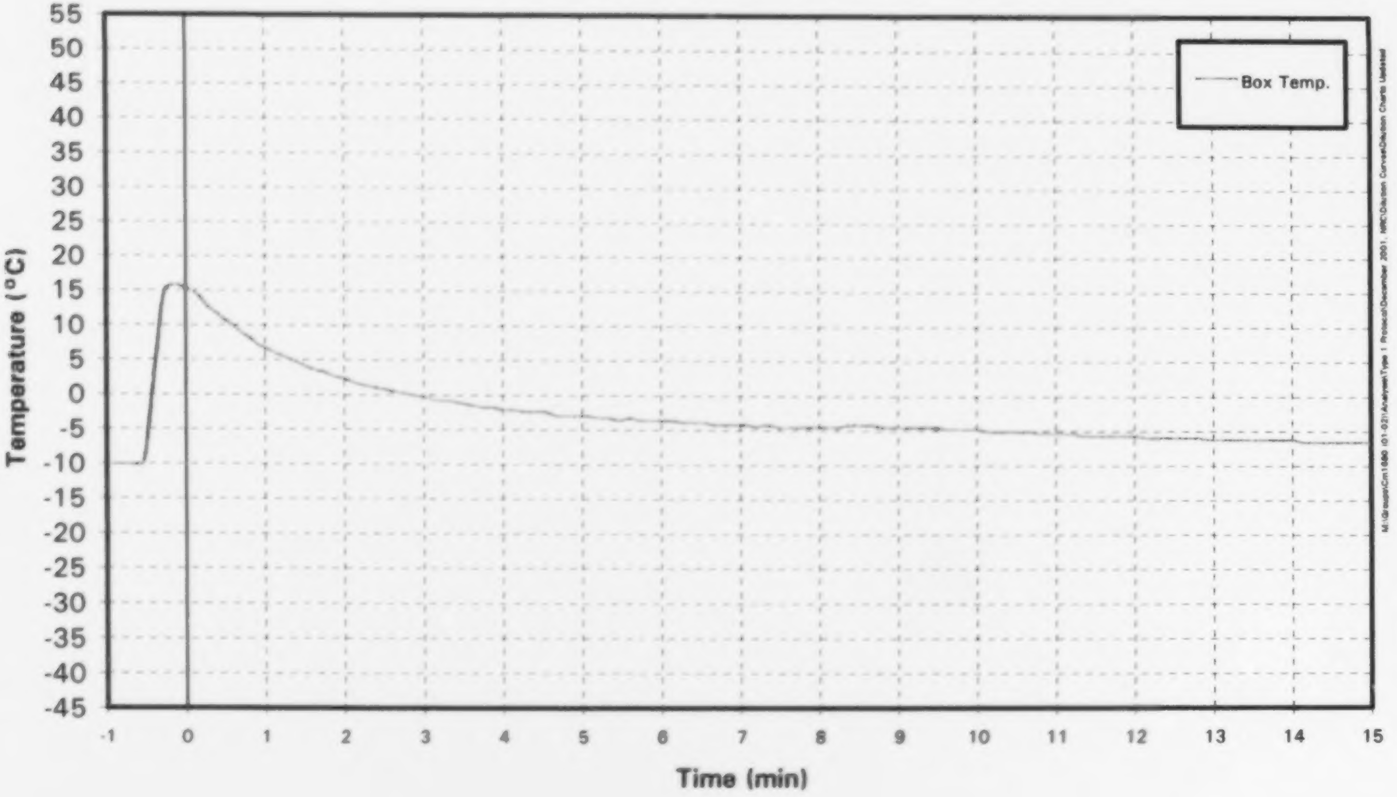
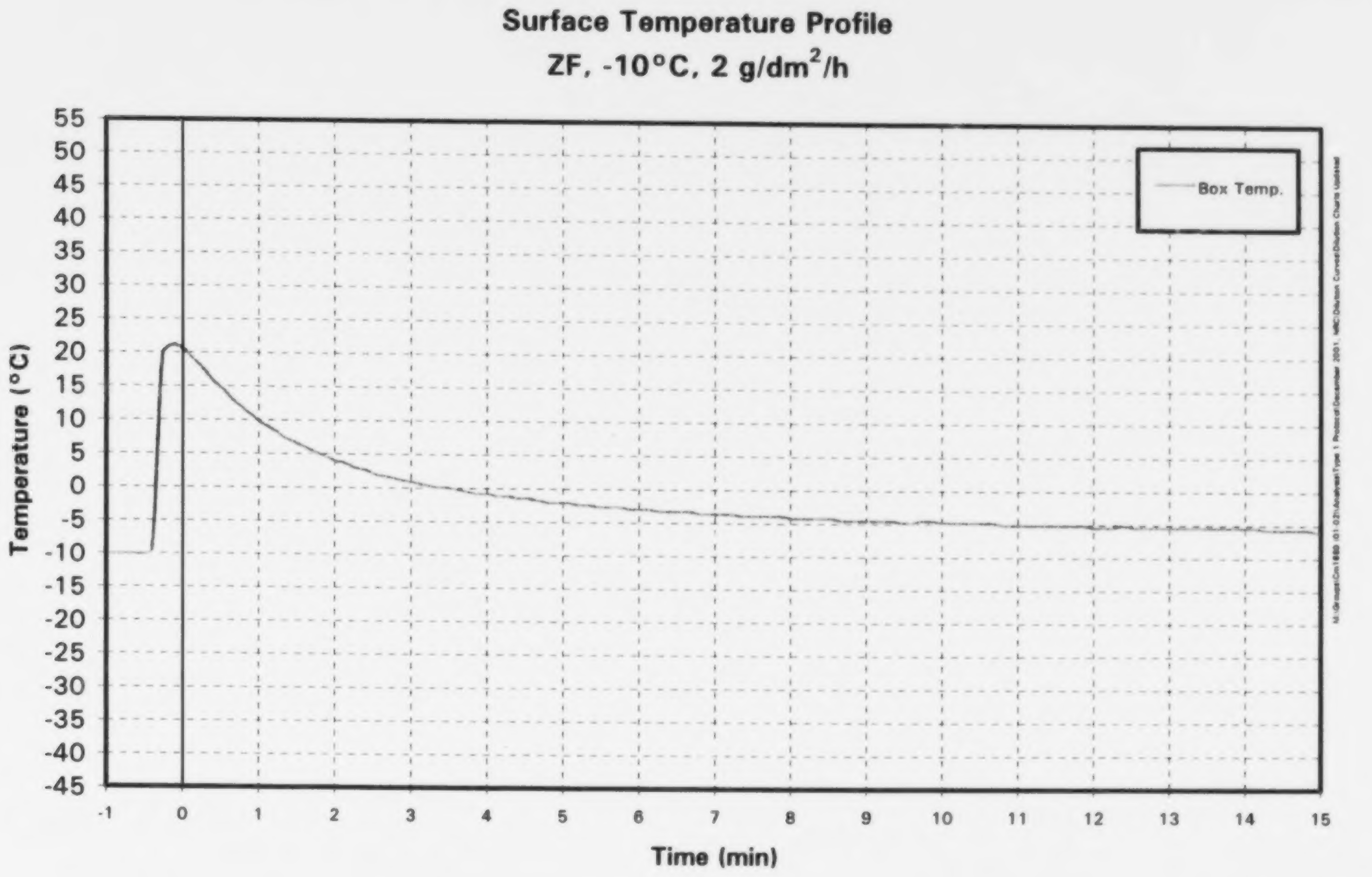

Surface Temperature Profile
ZF, -25°C, 2 g/dm²/h
Box Temp.
Temperature (°C)
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (min)



Surface Temperature Profile
ZF, -10°C, 5 g/dm²/h


Surface Temperature Profile
ZF, -10°C, 2 g/dm²/h
Box Temp.
Temperature (°C)
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (min)

F

APPENDIX F

DETERMINATION OF INDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL AND AN ADJUSTED AIR TEMPERATURE

- PROCEDURE
- RESULTS

CM1680.001

EXPERIMENTAL PROGRAM
DETERMINATION OF INDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL AND AN ADJUSTED AIR TEMPERATURE

- Freezing Fog
- Freezing Drizzle and Light Freezing Rain

Prepared by: Peter Dawson and John D'Avirro
Reviewed by: John D'Avirro

APS AVIATION INC. APS

February 14, 2002
Version 1.0

EXPERIMENTAL PROGRAM
DETERMINATION OF INDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL AND AN ADJUSTED AIR TEMPERATURE

This document describes the detailed procedures and equipment required for the conduct of freezing fog, freezing drizzle, and light freezing rain endurance time tests. These tests will be conducted at NRC's Climatic Engineering Facility (CEF) in Ottawa.

1. BACKGROUND

Endurance Time tests have traditionally used flat plates as testing surfaces. In a study completed after the 2000-2001 winter (TP 13827E) it was concluded that the Type I test procedure with flat plates, when conducted outdoors in natural wind did not provide a good simulation of actual deicing operations and did not produce a surface temperature decay rate that matched real wings. Shortened fluid endurance times would result. A new protocol that would more closely simulate Type I anti-icing operations under natural conditions was developed to address these deficiencies.

Following examination of several test surfaces and various procedures for fluid application, it was concluded that a 7.5 cm cold-soak box, empty, when treated with 0.5 L of fluid at 60°C, produced a reasonable representation of the temperature decay rate demonstrated by wing leading edges in natural outdoor conditions.

Subsequent to these findings for the outdoor tests, the FAA requested that a similar protocol with heated fluid be developed for indoor tests. To address this, APS recently (early December, 2001) carried out surface temperature profile tests at the PMG Cold Chamber Facility, in Blainville, Quebec. The indoor tests showed that the cold-soak box test surface would still follow the desired temperature profile if the fluid quantity was decreased to 0.25L and the number of holes in the spreader is increased from 12 to 24.

Endurance time tests were subsequently carried out at the NRC Canada Facility in December using the procedure "Determination of Indoor Endurance Times Type I Fluids Using the New Test Protocol". The results showed that the water temperature from the spray delivery system has an effect on the surface temperature, particularly in conditions with large droplets and high precipitation rates. This effect needs to be evaluated and tests may need to be redone.

1.1 Procedure to Calibrate Chamber Temperature to Provide Required Surface Temperature

Attachment F-V contains the procedure to calibrate the cold chamber temperature in order to achieve the surface temperature on boxes that are desired. This calibration will provide "set temperatures" for the chamber for each condition to be tested. Attachment F-V also provides the background relating to the need for these adjustments. The testing described in Attachment F-V will be carried out prior to the endurance time testing.

2. OBJECTIVES AND GENERAL TEST PLAN

2.1 Objectives

The objective of this test program is to establish indoor endurance times for Type I over the range of HOT table conditions. The tests will be conducted on cold soak boxes. Testing will be conducted using the newly developed (PMG) test protocol that uses the box with 0.25L of heated fluid. Scheduling of the indoor tests will be coordinated with the NRC. It is anticipated that the tests will begin the week of March 4, 2002, and continue the week of March 25th or April 3rd. The duration of the tests will be about ten days, including set-up time. At least four days are anticipated for the tests described in Attachment F-V and three days for the endurance time tests described herein. Fluid failure will be determined by visual observation.

Dilution measurements will be made on the cold soak boxes. Also, temperature profiles will be measured.

2.2 Test Plan and General Sequencing

There are 16 condition combinations from which indoor Type I tests are normally carried. Two conditions (cold-soak wing at high and low rates) will not be tested because the air temperature for these tests is $^{+}1^{\circ}$ and this is not a concern. The remaining 14 conditions are outlined in Table F-1.

Table F-1: Starting Chamber Temperature For Calibration Runs

Type of precipitation	Item #	Rate	OAT (°C)	Stabilized Box temp (°C)	Starting chamber Temp for calibration (°C)	Day*
Freezing Rain	1	13	-3	0	-20	3
	2	13	-10	-1	-30	2
	3	25	-3	+1	-30	3
	4	25	-10	0	-40	2
Freezing Drizzle	5	5	-3	0	-8	
	6	5	-10	-5	-20	1
	7	13	-3	+1	-10	
	8	13	-10	-4	-25	1
Freezing Fog	9	2	-3		-8	
	10	2	-10	-6	-12	4
	11	2	-25	-20	-30	4
	12	5	-3		-7	
	13	5	-10	-7	-14	
	14	5	-25	-19	-30	

*Tests that are to be conducted on days 5 to 8 will be scheduled at a later date

For each condition, the sequencing will be as follows:

1. Achieve desired rates at the start temperature.
2. Adjust the chamber temperature as required to "home in" to the desired box surface temperature.
3. Carry out endurance time tests on four boxes (two treated with ethelyne and two treated with propelyne fluid).

The anticipated schedule of tests is also provided in this document (See Attachment F-I).

3. PERSONNEL

The personnel required is provided below:

Coordinator (JD/PD):	Coordinate and supervise tests.
Leader (RC or MC):	Determine test fluids and positioning of tests on stand. Determine endurance times. Prepare heated fluids; prepare fluids for next tests.
Computer Technician (NM):	Enter data (rate and failure times) as collected. Evaluate data from loggers. Measure Brix on surfaces.
Weigh Scale Technician (YOW1):	Measure precipitation rates; complete general forms. Assist in test preparation
Fluid Application (YOW2):	Ensure plates are clean; application of fluids.

4. PROCEDURES

4.1 Tests to Set Temperatures

Attachment F-V contains the detailed procedure.

4.2 Endurance Time Tests

For the 7.5 cm cold-soak box, the recommended fluid temperatures are 60°C with an acceptance range of +2°C and -0°C. The recommended quantity is 0.25 L, and the fluid will be applied on the surface through a spreader with 24 holes. The fluid used will be diluted to a freeze point 10°C below ambient temperature.

The fluid will be mixed to a specific temperature dilution as per Attachment F-IV. A brixometer will be used to verify the dilution.

In addition to the regular test temperatures for Type I fluids, tests will be carried out at -3 °C, as shown in the Test Plan (Attachment F-II).

The tests will be conducted using propylene-based (Clariant MPI 1938 TF) and ethylene-based (DOW ADF) Type I fluids, according to the Test Plan.

5. TEST PLAN

The test schedule for CEF tests and the detailed test plan are included in this document. See Attachment F-I and Attachment F-II.

6. EQUIPMENT

Test equipment required for the flat plate tests was determined from previous winters in association with the Society of Automotive Engineers (SAE) working group on ground deicing. The complete equipment list for CEF tests is shown in Attachment III. The list includes the equipment that is necessary for the tests to be carried out using the new test protocol.

The 7.5 cm cold-soak boxes were insulated by Polybrand Inc. The boxes were covered with Dow Tryme 2000 Insulation cut to a thickness of ¾". The insulation was adhered to the boxes using Permatec Silicone Gasket Sealant. They were finally coated with eight coats of BASF Polymer Coating (120 mL).

7. DATA FORMS

The data forms for tests conducted in simulated conditions are as follows:

- General Form For Each Session At NRC, Form 1;
- Test Stand Location For Each Condition, Form 2;
- General Form For Each Condition, Form 3;
- Chamber Settings For Each Condition, Form 4;
- De/anti-icing Data Form For Freezing Precipitation, Form 5;
- Rate Management Form, Form 6; and
- Brix Measurement Form, Form 7.

Form 1
General Form for Each Session at NRC

LOCATION: CEF (Ottawa) **DATE INTERVAL:**

Safety Issues Discussed ☐

Test Plate Material: ☐
(check the box if material used is Aluminum alloy AMS 4037)

Test Plate Dimensions: ☐
(check the box if the dimensions are 500mm long x 300mm wide x 3.2mm thick)

Test Box Dimensions: ☐
(only for CSW, check the box if the dimensions are 500mm long x 300mm wide x 75mm thick)

Surface Finish: ☐
(check the box if the average surface roughness is less then or equal to 0.5 µm)

Ice-catch Pan Dimensions: ☐
(check the box if the dimensions are 406mm long x 279mm wide with a 64mm height)

Water Supply to Nozzle: ☐
(check the box if the water is ASTM D1193, Type IV)

Weigh Scale verification: 2g ☐ 100 g ☐
(see calibration procedure)

Air Temperature (°C):
(to be recorded by the NRC at a sampling rate of minimum 1 datum per minute and handed in to APS at the end of the session on floppy disks)
The air temperature data is saved to the following files (provide filename and extension):

Relative humidity (%):
(to be recorded by the NRC and handed in to APS at the end of the session on floppy disks)
The humidity data is saved to the following files (provide filename and extension):

COMMENTS:

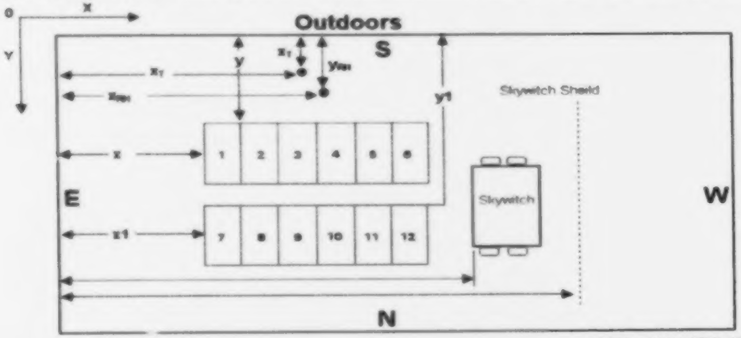
LEADER: ____________

CM1680(01-02)\Procedures\Type I Protocol\NRC, March 2002\Version 1.0\Forms\Form 1

Form 2
Test Stand Location for Each Condition

LOCATION: CEF (Ottawa)
DATE:
CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF26H ZF26L CSWH CSWL

Test	Date of Final Position	Condition	T / RH				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						
1	4-Apr-01	ZR3H					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
2	4-Apr-01	ZR3L					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
3	4/2/01	ZR10H					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft from snow fence
4	2-Apr-01	ZR10L					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft from snow fence
5	27-Mar-01	ZD3H					24' 5"	6'6"	22'	10'4"				Very Good		
6	28-Mar-01	ZD3L					25' 3"	7'3"	25' 3"	9' 6"				Good		
7	2-Apr-01	ZD10H					24'	7'11"	25' 3"	9' 6"				Very Good		
8	2-Apr-01	ZD10L					24'	7' 7"	24' 7"	9' 11"				Good		20 ft from Snow Fence
9	10-Apr-01	ZFog3H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
10	10-Apr-01	ZFog3L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
11	10-Apr-01	ZFog10H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
12	10-Apr-01	ZFog10L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Guud	144"	
13	9-Apr-01	ZFog14H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
14	9-Apr-01	ZFog14L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
15	6-Apr-01	ZFog25H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
16	6-Apr-01	ZFog25L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
17	29-Mar-01	CSWH					25'3"		25'3"	9' 6"						
18	29-Mar-01	CSWL					23'11"	7'3"	25'3"	9' 6"						



Notes:
* - "From X" refers to the distance from the East wall
** - The nozzle should be between positions 5 and 11
RH - Relative Humidity Sensor
T - Temperature Sensor

WEIGH SCALE TECHNICIAN ____________________

LEADER ____________________

NEW VALUES (IF DIFFERENT)

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						

[illegible]

Form 3
General Form for Each Condition

LOCATION: CEF (Ottawa)	DATE:	CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL

	PLATE 1	PLATE 6	PLATE 7	PLATE 12
Angle of the Test Stands (°):				

Distance between Nozzle and Test Plates (m): ☐
(check the box if distance is 144" for ZF and 7±0.5m for ZD, ZR and CSW)

Plate Temperature (°C):
(to be recorded by APS at the end of the each condition, saved on floppy disks and included in the envelope along with the forms)
The plate temperature data is saved to the following files (provide filename and extension):

COMMENTS:

COMPUTER TECHNICIAN: ____________

LEADER: ____________

Form 4
Chamber Setting for Each Condition

LOCATION: CEF (Ottawa)	DATE:	CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL

CONDITION	Needles Used	Flow Rate of Water *	Line Air Pressure (psi)	Line Air Temperature (Celsius)	Line Water Pressure (psi)	Line Water Temperature (Celsius)	Relative Humidity (%)	X Axis Area	Speed	Y Axis Area	Speed	Brace Height (inches)	LTS on						MTS on						Last Date
													1	2	3	4	5	6	1	2	3	4	5	6	
ZR 3 L	**2x20**	**1 GPM**	**60**	**12.5**	**78**	**2**	**75**	**full**	**low**	**full**	**high**		y	y					y	y	y				**4-Apr-01**
ZR 10 L	2x20	1 GPM	60	12.5	82	2.5	75	full	low	full	high			y					y	y	y				3-Apr-01
ZR 3 H	**2x20**	**1 GPM**	**60**	**12.5**	**61**	**2**	**75**	**partial**	**low**	**full**	**high**								y	y	y				**4-Apr-01**
ZR 10 H	2x20	1 GPM	60	12.5	78	2.5	73	partial	low	full	high			y					y	y	y				3-Apr-01
ZD 3 L	2x24	1 GPM	60	13	65	2.5	75	partial	low	full	high								y	y	y				28-Mar-01
ZD 10 L	2x24	1 GPM	60	12	43	2	76	full	low	full	high			y					y	y	y				30-Mar-00
ZD 3 H	2x23	1 GPM	60	13	62	2.5	90	partial	low	full	high								y	y	y				27-Mar-01
ZD 10 H	2x23	1 GPM	60	12	55	2.5	72	partial	low	full	high		y	y					y	y	y				30-Mar-00
FOG 3 L	1 X 20/50/120	80	80	80	-	73.3	96	full	low	full	low	144							y	y	y				5-Apr-01
FOG 14 L	1 x 20/50/120	55	40	72	-	72.8	80	full	low	full	low	144							Y	Y	Y				11-Apr-01
FOG 25 L	1 x 20/50/120	50	40	72	-	72.8	80	full	low	full	low	144	y	y	y										6-Apr-01
FOG 3 H	1X 20/50/120	75	40	72	-	73.2	95	full	low	full	low	144							y	y	y				10-Apr-01
FOG 14 H	1 x 20/50/120	75	40	73	-	72.8	76	full	low	full	low		y						y	y	y				9-Apr-01
FOG 25 H	1 x 20/50/120	75	40	73	-	73.2	73	full	low	full	low	144	y	y	y										6-Apr-01
CSW 1 H	2x17	1 GPM	60	13.5	75	2	85	part	low	full	high										y	y		y	4-Jun-01
CSW 1 L	2 x 24	1 GPM	60	12.5	30	2.5	89	full	low	full	high										y	y			4-Jun-01
ZD 10 5	2 x 24	1 GPM	60	15	35	4.5	-												y	y	y				16-Jul-99
FOG 35 H	1 X 20/50	12	40	74	-	-	-	partial	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 35 L	1 x 20/50	10	40	73	-	-	-	full	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 30 L	1 x 20/50	10	40	73	-	-	-	full	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 32 L	1 x 20/50	13	40	-	-	-	-	partial	low	full	low	104	y	y	y	y									20-Jul-99
FOG 32 H	1 x 20/50	24	40	-	-	-	-	full	low	full	low	144	y	y	y	y									20-Jul-99
FOG 10 H	1 x 20/50	75	40	74	-	72.6	-	full	low	full	low	144							y	y	y				9-Apr-01
FOG 10 L	1 X 20/50	55	40	-	-	-	-	full	low	full	low	144							y	y	y				9-Apr-01
FOG25L	1x20/50/120	15	40	73	-	70.9	-	full	low	full	low	144		y	y	y									31-Mar-00
FOG25h	1x20/50/120	24	40	79	-	72.9	-	full	low	full	low	144	y	y	y										4-Apr-00
ZR3H-2	2X20	1GPM	60	12.5	90	1.5	-	partial	low	full	high								y	y	y				6-Apr-00

* Dial Readings=X ⟶ Flow Rate for Fog (ml/min) = $0.0033 \cdot X^2 + 3.3605 \cdot X - 17.512$

Brace height 12'6"

NEW VALUES (IF DIFFERENT)

CONDITION	Needles Used	Flow Rate of Water*	Line Air Pressure (psi)	Line Air Temperature (Celsius)	Line Water Pressure (psi)	Line Water Temperature (Celsius)	Relative Humidity (%)	X Axis Area	Speed	Y Axis Area	Speed	Brace Height (inches)	LTS on						MTS on						Date
													1	2	3	4	5	6	1	2	3	4	5	6	

COMPUTER TECHNICIAN:____________________ LEADER: ____________________

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Form 5
De/Anti-Icing Data Form for Freezing Precipitation

REMEMBER TO SYNCHRONIZE TIME

VERSION 1.1 2001/2002

LOCATION: CEF (Ottawa) **DATE:** **RUN NUMBER:** **STAND # :**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application:	______	______	______	______	______	______
Initial Fluid Temperature (°C)	______	______	______	______	______	______
Initial Plate/BOX Temperature (°C)	______	______	______	______	______	______
Initial Brix	______	______	______	______	______	______
	Plate/BOX #	**Plate/BOX #**	**Plate/BOX #**	**Plate/BOX #**	**Plate/BOX #**	**Plate/BOX #**
FLUID NAME						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
Final Temperature / Brix						
FAILURE CALL (circle)	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy
HRZ. AIR VELOCITY * (circle)	A B C	A B C	A B C	A B C	A B C	A B C

Time of Fluid Application:	______	______	______	______	______	______
Initial Fluid Temperature (°C)	______	______	______	______	______	______
Initial Plate/BOX Temperature (°C)	______	______	______	______	______	______
Initial Brix	______	______	______	______	______	______
	Plate/BOX #	**Plate/BOX #**	**Plate/BOX #**	**Plate/BOX #**	**Plate/BOX #**	**Plate/BOX #**
FLUID NAME						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
Final Temperature / Brix						
FAILURE CALL (circle)	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy	V Difficult Difficult Easy
HRZ. AIR VELOCITY * (circle)	A B C	A B C	A B C	A B C	A B C	A B C

PRECIP (circle): ZF , ZD , ZR-, CSB **AMBIENT TEMPERATURE:** ______ °C

COMMENTS: ____________________

____

____

NOTE:
- * **A: HORIZONTAL AIR VELOCITY ≤ 0.4 m/s**
- **B: 0.4 m/s < HORIZONTAL AIR VELOCITY ≤ 1.0 m/s**
- **C: HORIZONTAL AIR VELOCITY > 1.0 m/s**

LEADER / MANAGER: ____________________

*To compare to previous years of testing, subtract "Time of Fluid Application"

CM1680(01-02)\Procedures\Type I Protocol\NRC, March 4th 2002\Version 1.0\Forms\Form 5

Form 6
Rate Management Form

DATE: __________ **WEIGH SCALE TECHNICIAN:** ____________________

PAN #	TIME OUT	1^{st} or 2^{nd} Rate

PAN #	TIME OUT	1^{st} or 2^{nd} Rate

This form is for guidance to manage the sequencing of pans measurement.

[illegible]

Form 7
Fluid Brix Test

DATE: ______________
RUN #: ______________
STAND: ______________

PERFORMED BY: ______________
WRITTEN BY: ______________
LOCATION: ______________

BRIX					
Plate: Fluid:		Plate: Fluid:		Plate: Fluid:	
TIME	**6" LINE**	**TIME**	**6" LINE**	**TIME**	**6" LINE**

[illegible]

Attachment F-I
Tentative Schedule

March 4, 2002
Monday

7 AM	
8:00	SETUP, cool to -25°C (previous night)
9:00	ZD @ -10, 13 (Set Temperature)
10:00	
11:00	
12 PM	ZD @ -10, 13 (ET Tests)
1:00	ZD @ -10, 5 (Set Temperature)
2:00	
3:00	
4:00	ZD @ -10, 5 (ET Tests)
5:00	
6:00	
7:00	

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Attachment F-I
Tentative Schedule

March 5, 2002
Tuesday

7^{AM}	
8^{00}	STARTUP
9^{00}	ZR @ -10, 13 (Set Temperature)
10^{00}	
11^{00}	
12^{PM}	ZR @ -10, 13 (ET Tests)
1^{00}	ZR @ -10, 25 (Set Temperature)
2^{00}	
3^{00}	
4^{00}	ZR @ -10, 25 (ET Tests)
5^{00}	
6^{00}	
7^{00}	

CM1680(01-02)\Procedures\Type I Protocol\NRC, March 4, 2002\Version 1.0\Calendar

Attachment F-I
Tentative Schedule

March 6, 2002
Wednesday

7^{AM}	
8^{00}	STARTUP
9^{00}	ZR @ -3, 13 (Set Temperature)
10^{00}	
11^{00}	
12^{PM}	ZR @ -3, 13 (ET Tests)
1^{00}	ZR @ -3, 25 (Set Temperature)
2^{00}	
3^{00}	
4^{00}	ZR @ -3, 25 (ET Tests)
5^{00}	
6^{00}	
7^{00}	

CM1680(01-02)\Procedures\Type I Protocol\NRC, March 4, 2002\Version 1.0\Calendar

Attachment F-I
Tentative Schedule

March 7, 2002
Thurday

7^{AM}	
8^{00}	STARTUP
9^{00}	Zfog @ -10, 2 (Set Temperature)
10^{00}	
11^{00}	
12^{PM}	Zfog @ -10, 2 (ET Tests)
1^{00}	Zfog @ -25, 2 (Set Temperature)
2^{00}	
3^{00}	
4^{00}	Zfog @ -25, 2 (ET Tests)
5^{00}	
6^{00}	
7^{00}	

CM1680(01-02)\Procedures\Type I Protocol\NRC, March 4, 2002\Version 1.0\Calendar

Attachment F-II
CEF Detailed Test Plan - Type I

Test #	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	Dilution [%] 10° Buffer XL54 Premix	Fluid Temp. [°C]	Fluid Initial Brix	Applic. Method	Quantity [L]	Glycol Type	Surface	HOT
1	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
2	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
3	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
4	Freezing Drizzle	-3	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
5	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
6	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
7	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
8	Freezing Drizzle	-3	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
9	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
10	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
11	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
12	Freezing Drizzle	-10	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
13	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
14	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
15	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
16	Freezing Drizzle	-10	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
17	Freezing Fog	-3	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
18	Freezing Fog	-3	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
19	Freezing Fog	-3	2	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
20	Freezing Fog	-3	2	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
21	Freezing Fog	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
22	Freezing Fog	-3	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
23	Freezing Fog	-3	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
24	Freezing Fog	-3	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
25	Freezing Fog	-10	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
26	Freezing Fog	-10	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
27	Freezing Fog	-10	2	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
28	Freezing Fog	-10	2	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
29	Freezing Fog	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
30	Freezing Fog	-10	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
31	Freezing Fog	-10	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
32	Freezing Fog	-10	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
33	Freezing Fog	-25	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
34	Freezing Fog	-25	2	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
35	Freezing Fog	-25	2	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
36	Freezing Fog	-25	2	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
37	Freezing Fog	-25	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
38	Freezing Fog	-25	5	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
39	Freezing Fog	-25	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
40	Freezing Fog	-25	5	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
41	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
42	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
43	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
44	Light Freezing Rain	-3	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
45	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
46	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
47	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
48	Light Freezing Rain	-3	25	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
49	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
50	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
51	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
52	Light Freezing Rain	-10	13	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
53	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
54	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	UCAR ADF	Cold Soak Box	
55	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	
56	Light Freezing Rain	-10	25	10°	60		Spreader	0.25	MPI 1938TF	Cold Soak Box	

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Attachment F-III
NRC Cold Chamber Tests – March 2002-02-13
Test Equipment Checklist

TASK	*NRC Cold Chamber*	
	Resp.	Status
Make Hotel reservations		
Rent Van/Car		
Test Equipment		
Stand 2X3 and 2X6 + collection pans	NB	
NCAR snow machine		NO
Water for snowmaker		NO
Hand-Held Temperature Probes X 2	NB	
Hard water for dilution (20 L)	NB	
Cups to pour 1 litre of Type I (X 12)	NB	
Precipitation rate software (Observer)	NM	
Birds eye view camera	NB	
Covers for CSW	NB	
CSW equipment	NB	
Sump Pumps		NO
Labtop Computer x 2	NM	
Still Photo Camera	NM	
Digital Video Camera	NM	
Weigh Scales x 2	NB	
Video Camera X 2 (Surf & Snow) + Access	NB	
Reg. Plates X 12	NB	
Data Forms for plates	NM	
Precipitation rate Data Forms	NB	
Reports + Tables (Temperature conversion, Dilution,)	NM	
Large Precipitation Pans x 36	NB	
Type I Fluids	NB	
Type IV Fluids	NB	
Clipboards x 3	NB	
Pencils + Space pens x 4	NB	
Paper Towels	NB	
Rubber squeegees	NB	
Plastic Refills for Fluids and funnels	NB	
Electrical Extension Cords	NB	
Lighting x 2	NB	
Clock	NB	
Storage bins for small equipment	NB	
Protective clothing (All)	NB	
Brixometer X 3	NB	
Tie wraps	NB	
Funnels	NB	
Thickness Gauges	NB	
Microscope & Accessories	NB	
Big Digital Clock	NB	
Scrapers	NB	
Cooling Unit + fluid for it		NO
Cold-Soaked Boxes 7.5 cm X 6 cm	NB	
Thermocouple Kit + Logger for CSW	NB	
Digital level	NB	
Test Procedures X 10	NM	
Fluid waste containers	NB	
Shopvac	NB	
Printer (Epson)	NM	
Detailed rate pans	NB	
Paint brushes for plate cleaning		NO
Red containers	NB	
Headsets		NO
Rate shelf	NB	
Empty bottles for samples		NO
Computers and monitors	NM	
Measurement containers X 2	NB	
Cradles	NB	
Excel software for detailed rates	NM	
Weigh Scale (1 gram)	NB	
Preweigh minerals	NB	
Big Plastic container		NO
Washers	NB	
Standard Spreaders, small holes X 2	NB	
Measuring cup kit (250/500/1000mL) X 2each	NB	
Hot Stoves X 2	NB	
Microwave	NB	
Drum craddles X 2	NB	
Drum valves X 2	NB	
Thermoses 2 X 6	NB	
Dolly	NB	
Wind Gauge	NB	
Weights X 2 sets	NB	
Distance Measurement Instrument	NM	
Boxes elbows X 4	NB	
Spray Bottles X 2	NB	
Envelopes / Time Cards / Invoices	NM	
Diskettes	NM	
Thermistor probes X 7	NB	
Loggers X 2	NB	
Logger Interface	NB	
Aluminium Speed Tape	NB	
Heat Gun	NB	
Starter Fluid	NB	

[illegible]

Attachment F-IV
Fluid Mixtures for Type I Tests

Fluid	Brix for OAT of								
	-25°C (FP -35°C)*			-10°C (FP -20°C)			-3°C (FP -13°C)		
	Brix	Glycol/ Litre (ml)	Water/ Litre	Brix	Glycol/ Litre (ml)	Water/ Litre (ml)	Brix	Glycol/ Litre (ml)	Water/ Litre (ml)
Lyondell Arco +	35.8	568	433	27.5	425	575	23.0**	352	648
UCAR ADF	30.0	490	510	22.5	360	640	17.0	260	740
Clariant MPI 1938 TF	35.0	640	360	28.0	480	520	22.5	392	608

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* Assumes this mixture meets aerodynamics performance.

Attachment F-V

Procedure For Calibrating the Cold Chamber Ambient Temperature To Produce the Desired Test Surface Temperature During Precipitation

1. REQUIREMENT

Previous Type I fluid endurance tests in artificial freezing precipitation have shown that test surfaces exposed to the precipitation have taken on a temperature higher than the chamber ambient temperature. This is believed to be caused by raindrops (hitting the test surfaces) that have not had time during their descent from the nozzle to cool from their initial value (2 to 3°C). In natural conditions, the droplet temperature for freezing rain or drizzle is believed to be close to ambient, and therefore does not change surface temperature.

The higher test surface temperature influences the measured endurance time and therefore needs to be resolved.

The proposed method for bringing the test surface to the temperature specified by test parameters is to gradually cool the surrounding air beyond that temperature level desired. At some point, the additional cooling caused by the colder air will cause the droplet temperatures to fall to a value where their impact on the test surface will produce the desired temperature.

2. PROCEDURE

2.1 General

The ambient air temperature needed to produce the desired result will be different for each combination of specified test conditions (OAT, type of freezing precipitation, rate). Each combination will require separate examination and calibration.

Only the cold-soak box test surface will be used in this calibration.

The examination of each combination will involve a series of iterative runs to determine the temperature of the surrounding air that is needed for producing the desired result.

2.2 Steps

1. Set up the test stand in the normal position for testing in that specific freezing precipitation condition, as established from previous fluid endurance tests.
2. For the first run of each set, as a start point, set the chamber ambient temperature at a differential value below the test specification, using values shown in Table 1 in Section 2.2 in the main procedure (based on results of previous tests).
3. Install thermistor probes on three box surfaces.
4. Establish freezing precipitation over the stand at the rate required. The precipitation will run continuously through the calibration process (without parking the sprayer) to maintain a stable condition over the stand.
5. Position the boxes on the stand locating one box at either end and one in the middle of the stand. Cover them until ready to apply the Type IV fluid.
6. Treat the box surfaces with a Type IV fluid applied at the desired temperature.
7. Monitor the box temperatures and note the temperature at which they stabilize.
8. Record details for each iteration using Table F-2.
9. Estimate the correction in chamber temperature required to reach the desired box temperature, and reset the chamber temperature accordingly.
10. Repeat step 7 and 8 until a stabilized box temperature equal to ±0.5°C of the temperature desired, has been produced.
11. The Type IV fluid may need to be renewed on the box surfaces to prevent freezing. Keep a container of fluid for this purpose in the stand area to maintain a fluid temperature near that desired.

Table F-2: Data Form for Chamber Temperature Calibration

Iteration #	Type of Precipitation	Rate	OAT	Desired Box Temp	Stabilized Box Temp

RESULTS

- LOG OF TESTS
- SUMMARY OF TYPE I RESULTS
- CALIBRATION RESULTS
- SURFACE TEMPERATURE PROFILES

Examination of Protocol for Type I Fluid Endurance Trials in a Lab Environment
Log of Tests

Seq. #	Plate Loc.	Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Fluid Name	Fluid Dilution	Surface	Application Method	Fluid Qty	Fluid Temp °	Fail Time (min)	Estimated Rate ($g/dm^2/hr$)	Ambient Temp (°C)	Actual Chamber Temp. (°C)	Precipitation (Type)	Comments
1	1	11-Mar-02	17:18:59	17:22:10	UCAR ADF	10	Box	Spreader	0.25	60	3.2	25	-10	-13	Light Freezing Rain	
2	2	11-Mar-02	17:20:15	17:24:37	UCAR ADF	10	Box	Spreader	0.25		4.4	25	-10	-13	Light Freezing Rain	
3	3	11-Mar-02	17:21:28	17:25:35	C1938	10	Box	Spreader	0.25	60	4.1	25	-10	-13	Light Freezing Rain	
6	6	11-Mar-02	17:22:26	17:28:00	C1938	10	Box	Spreader	0.25	59.7	5.6	25	-10	-13	Light Freezing Rain	
7	2	12-Mar-02	9:11:57	9:15:20	UCAR ADF	10	Box	Spreader	0.25		3.4	25	-10	-13	Light Freezing Rain	not completely covered
8	6	12-Mar-02	9:10:37	9:15:02	C1938	10	Box	Spreader	0.25	9	4.4	25	-10	-13	Light Freezing Rain	
9	4	12-Mar-02	9:24:25	9:27:59	UCAR ADF	10	Box	Spreader	0.25	60.5	3.6	25	-10	-13	Light Freezing Rain	
10	5	12-Mar-02	9:22:46	9:26:15	C1938	10	Box	Spreader	0.25	60.5	3.5	25	-10	-13	Light Freezing Rain	did not completely wet
11	2	12-Mar-02	10:55:05	10:59:50	UCAR ADF	10	Box	Spreader	0.25	57.2	4.8	13	-10	-12	Light Freezing Rain	
12	3	12-Mar-02	10:55:52	11:01:20	C1938	10	Box	Spreader	0.25	58.4	5.5	13	-10	-12	Light Freezing Rain	
13	4	12-Mar-02	11:06:09	11:10:50	UCAR ADF	10	Box	Spreader	0.25	57.8	4.7	13	-10	-12	Light Freezing Rain	
14	5	12-Mar-02	11:06:58	11:12:16	C1938	10	Box	Spreader	0.25	59	5.3	13	-10	-12	Light Freezing Rain	
15	2	12-Mar-02	13:10:38	15:16:02	UCAR ADF	10	Box	Spreader	0.25	59	125.4	13	-10	-11	Freezing Drizzle	
16	3	12-Mar-02	13:11:26	13:17:12	C1938	10	Box	Spreader	0.25	61	5.8	13	-10	-11	Freezing Drizzle	
17	4	12-Mar-02	13:21:35	13:27:20	UCAR ADF	10	Box	Spreader	0.25	60.5	5.8	13	-10	-11	Freezing Drizzle	
18	5	12-Mar-02	13:22:31	13:28:30	C1938	10	Box	Spreader	0.25	60.5	6.0	13	-10	-11	Freezing Drizzle	
19	2	12-Mar-02	14:53:35	15:01:50	UCAR ADF	10	Box	Spreader	0.25	60	8.3	5	-10	-10	Freezing Drizzle	
20	3	12-Mar-02	14:54:20	15:04:20	C1938	10	Box	Spreader	0.25	59.3	10.0	5	-10	-10	Freezing Drizzle	
21	1	12-Mar-02	15:11:05	15:18:40	UCAR ADF	10	Box	Spreader	0.25	61	7.6	5	-10	-10	Freezing Drizzle	T IV on box prior to pouring
22	4	12-Mar-02	15:08:35	15:18:32	C1938	10	Box	Spreader	0.25	60.3	10.0	5	-10	-10	Freezing Drizzle	
25	4	12-Mar-02	18:11:50	18:37:30	UCAR ADF	10	Box	Spreader	0.25	60.5	25.7	25	-3	-4	Light Freezing Rain	
26	5	12-Mar-02	18:10:50	18:35:25	C1938	10	Box	Spreader	0.25	61.4	24.6	25	-3	-4	Light Freezing Rain	
27	1	12-Mar-02	18:29:22	18:47:18	UCAR ADF	10	Box	Spreader	0.25	60.2	17.9	25	-3	-4	Light Freezing Rain	start box temp. was cold, not good coverage

Examination of Protocol for Type I Fluid Endurance Trials in a Lab Environment
Log of Tests

Seq. #	Plate Loc.	Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Fluid Name	Fluid Dilution	Surface	Application Method	Fluid Qty	Fluid Temp °	Fail Time (min)	Estimated Rate (g/dm²/hr)	Ambient Temp (°C)	Actual Chamber Temp. (°C)	Precipitation (Type)	Comments
28	6	12-Mar-02	18:30:35	18:55:46	C1938	10	Box	Spreader	0.25	60.8	25.2	25	-3	-4	Light Freezing Rain	
31	1	13-Mar-02	10:54:28	11:14:30	UCAR ADF	10	Box	Spreader	0.25	60	20.0	13	-3	-3.4	Freezing Drizzle	
32	2	13-Mar-02	10:53:28	11:12:43	C1938	10	Box	Spreader	0.25	60	19.3	13	-3	-3.4	Freezing Drizzle	
33	3	13-Mar-02	11:06:21	11:30:43	UCAR ADF	10	Box	Spreader	0.25	60	24.4	13	-3	-3.4	Freezing Drizzle	
34	4	13-Mar-02	11:07:01	11:31:48	C1938	10	Box	Spreader	0.25	60	24.8	13	-3	-3.4	Freezing Drizzle	
35	1	13-Mar-02	13:44:06	14:06:45	UCAR ADF	10	Box	Spreader	0.25		22.7	13	-3	-3.1	Light Freezing Rain	
36	2	13-Mar-02	13:43:13	14:08:30	C1938	10	Box	Spreader	0.25		25.3	13	-3	-3.1	Light Freezing Rain	
37	3	13-Mar-02	13:34:40	14:03:10	UCAR ADF	10	Box	Spreader	0.25		28.5	13	-3	-3.1	Light Freezing Rain	
38	4	13-Mar-02	13:35:40	14:03:40	C1938	10	Box	Spreader	0.25		28.0	13	-3	-3.1	Light Freezing Rain	
43	3	13-Mar-02	16:20:03	16:44:20	UCAR ADF	10	Box	Spreader	0.25	61.7	24.3	5	-3	-3.5	Freezing Drizzle	
44	4	13-Mar-02	16:19:18	16:41:30	C1938	10	Box	Spreader	0.25	61.8	22.2	5	-3	-3.5	Freezing Drizzle	
45	1	13-Mar-02	16:34:20	16:55:05	UCAR ADF	10	Box	Spreader	0.25		20.8	5	-3	-3.5	Freezing Drizzle	
46	2	13-Mar-02	16:33:14	16:56:22	C1938	10	Box	Spreader	0.25		23.1	5	-3	-3.5	Freezing Drizzle	
47	3	14-Mar-02	10:22:58	10:33:22	C1938	10	Box	Spreader	0.25	61.2	10.4	2	-25	-25	Freezing Fog	
48	1	14-Mar-02	10:30:01	10:42:44	C1938	10	Box	Spreader	0.25		12.7	2	-25	-25	Freezing Fog	
49		14-Mar-02	11:05:50	11:15:00	UCAR ADF	10	Box	Spreader	0.25	59.9	9.2	2	-25	-25	Freezing Fog	
50	4	14-Mar-02	12:09:50	12:16:00	UCAR ADF	10	Box	Spreader	0.25	60	6.2	5	-25	-25	Freezing Fog	
51	5	14-Mar-02	12:11:30	12:20:00	C1938	10	Box	Spreader	0.25	59.9	8.5	5	-25	-25	Freezing Fog	
52	3	14-Mar-02	12:25:45	12:32:45	UCAR ADF	10	Box	Spreader	0.25	60	7.0	5	-25	-25	Freezing Fog	
53	6	14-Mar-02	12:24:20	12:33:20	C1938	10	Box	Spreader	0.25	60.5	9.0	5	-25	-25	Freezing Fog	
54	4	14-Mar-02	16:36:00	16:44:32	UCAR ADF	10	Box	Spreader	0.25	60	8.5	5	-10	-24.7	Freezing Fog	
55	3	14-Mar-02	16:40:00	16:50:30	C1938	10	Box	Spreader	0.25	61.5	10.5	5	-10	-9.9	Freezing Fog	
56	2	14-Mar-02	18:06:00	18:22:00	UCAR ADF	10	Box	Spreader	0.25		16.0	2	-10	-9.8	Freezing Fog	
57	3	14-Mar-02	18:07:10	18:22:00	C1938	10	Box	Spreader	0.25		14.8	2	-10	-9.8	Freezing Fog	
60	6	14-Mar-02	18:09:10	18:24:30	Metss	10	Box	Spreader	0.25	60	15.3	2	-10	-9.8	Freezing Fog	
61	1	15-Mar-02	9:16:20	9:37:00	UCAR ADF	10	Box	Spreader	0.25		20.7	5	-3	-3.5	Freezing Fog	
63	3	15-Mar-02	9:09:10	9:27:00	C1938	10	Box	Spreader	0.25	59.8	17.8	5	-3	-3.5	Freezing Fog	
64	4	15-Mar-02	9:10:10	9:29:00	UCAR ADF	10	Box	Spreader	0.25	61	18.8	5	-3	-3.5	Freezing Fog	
65	5	15-Mar-02	9:15:10	9:34:40	C1938	10	Box	Spreader	0.25		19.5	5	-3	-3.5	Freezing Fog	
67	1	15-Mar-02	11:01:00	11:27:30	C1938	10	Box	Spreader	0.25	60	26.5	2	-3	-2.8	Freezing Fog	
68	2	15-Mar-02	11:02:10	11:23:40	UCAR ADF	10	Box	Spreader	0.25	60.4	21.5	2	-3	-2.8	Freezing Fog	
69	3	15-Mar-02	11:04:20	11:30:10	C1938	10	Box	Spreader	0.25	61	25.8	2	-3	-2.8	Freezing Fog	

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Log of Tests\Filtered Log

Summary of Type I Results
March 2002 – NRC
Freezing Drizzle, Light Freezing Rain, and Freezing Fog at –3°C

Based on Cold-Soak Box, empty, 0.25L fluid at 60°C

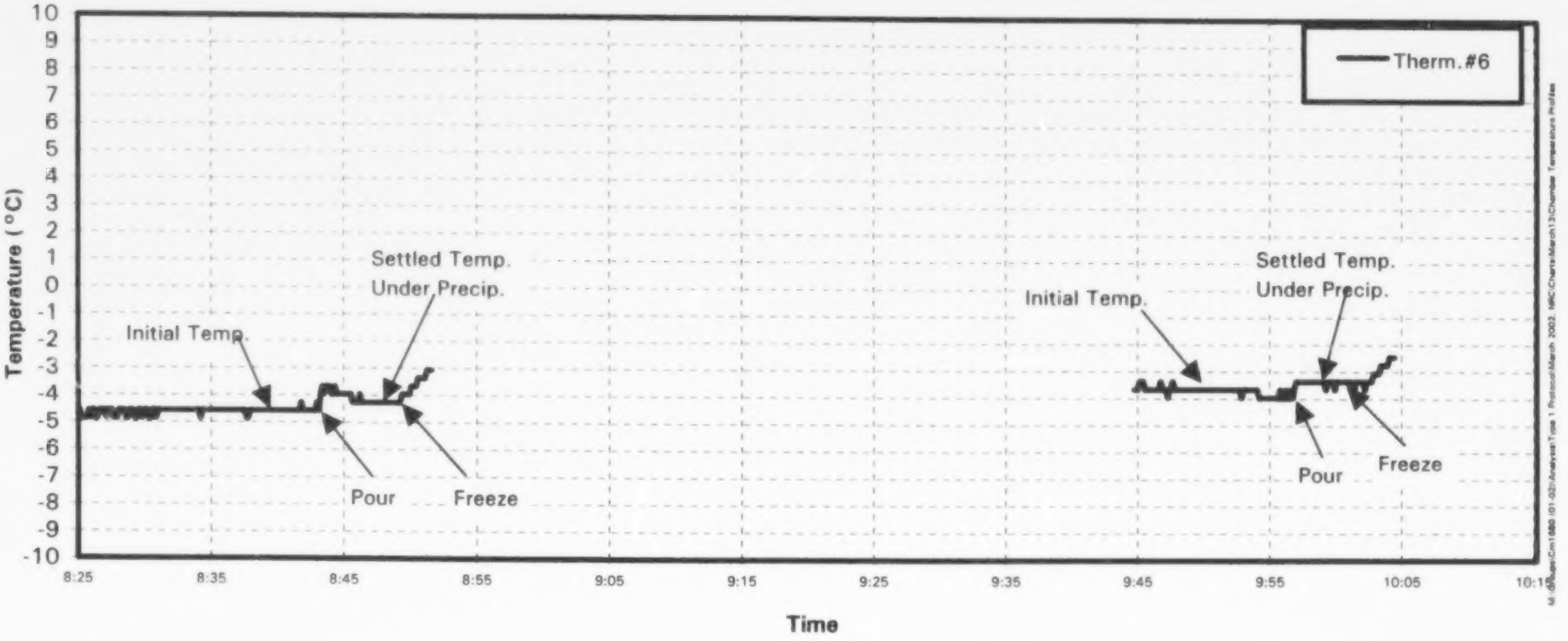
Precipitation			ZD		ZR		Zfog	
Temperature (°C)			-3		-3		-3	
Rate (g/dm²/h)			Low	High	Low	High	Low	High
			5	13	13	25	2	5
March 2002	UCAR ADF EG	Box 1	24:17	20:02	22:39	25:40	21:30	18:50
		Box 2	20:45	24:22	28:30	17:56	-	20:40
March 2002	Clariant MP I 1938 TF	Box 1	22:12	19:15	25:17	24:35	26:30	17:50
		Box 2	23:08	24:47	28:00	25:11	25:50	19:30
HOT			8	5	5	2	11	6

M:\Groups\Cm1680 (01-02)\Data\Type I Protocol\March 11-15, 2002, NRC\NRC-March 11-15 Summary of Results

Calibration Results

Type of Precipitation	Air Temperature (°C)	Rate of Precipitation ($g/dm^2/h$)	Observed Air to Box Differential (°C)
Light Freezing Rain	-10	25	-2.5
Light Freezing Rain	-10	13	-1.3
Freezing Drizzle	-10	13	-0.5
Freezing Drizzle	-10	5	-0.2
Light Freezing Rain	-3	25	-0.7
Freezing Drizzle	-3	13	0

Plate Temperature Profiles
ZD, -3°C, 13g/dm^2/h



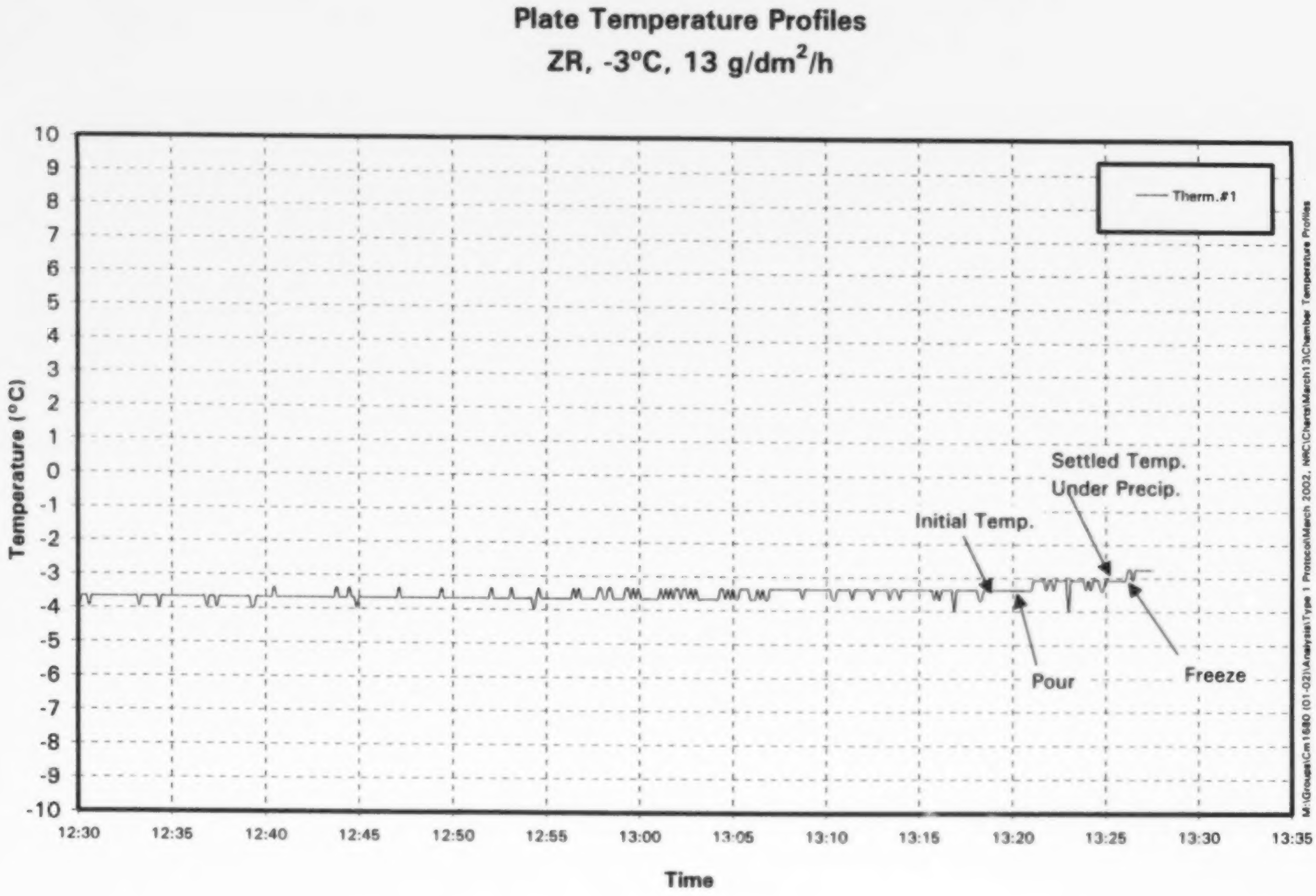
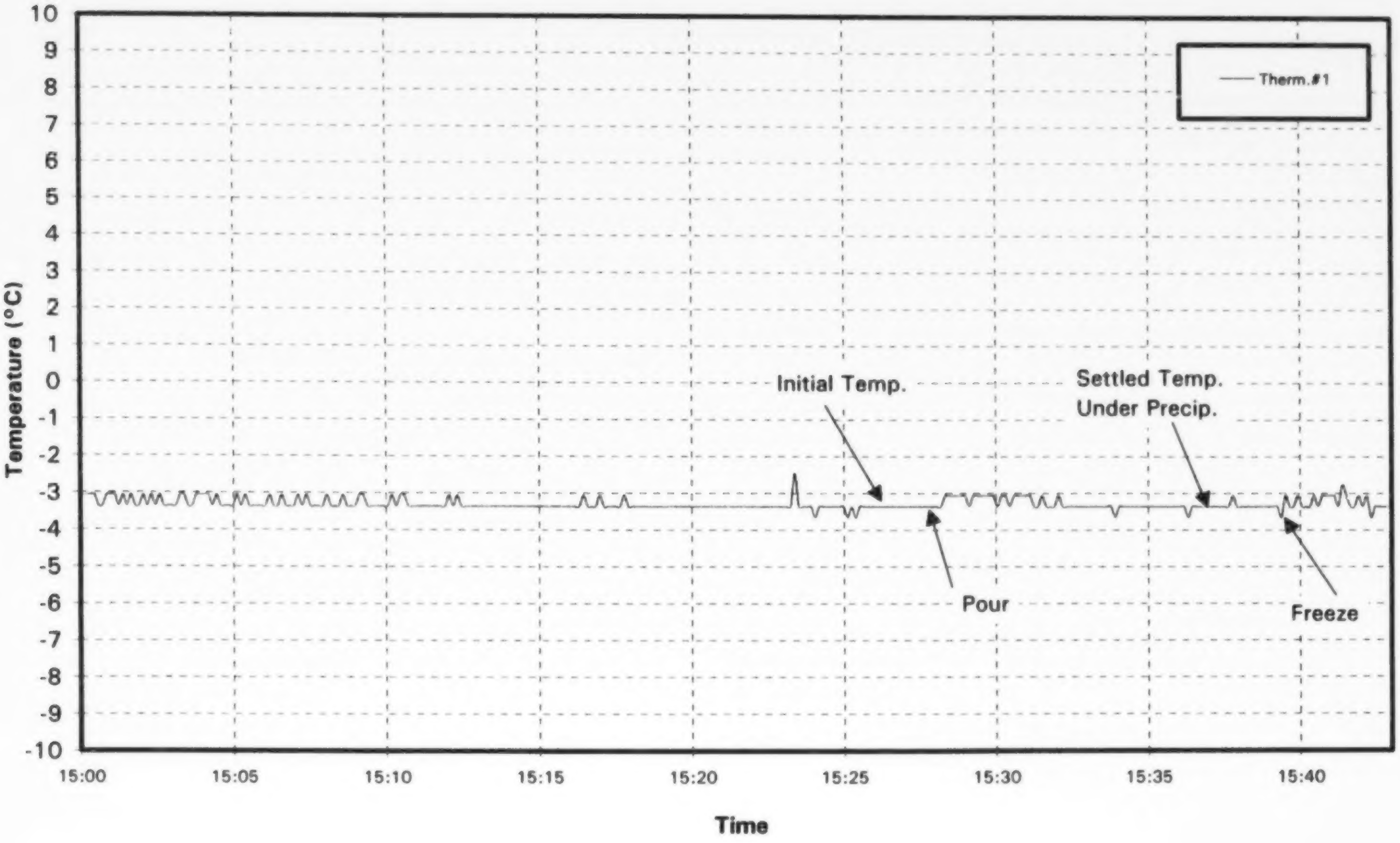


Plate Temperature Profiles
ZR, -3°C, 13 g/dm²/h
Therm.#1
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
12:30
12:35
12:40
12:45
12:50
12:55
13:00
13:05
13:10
13:15
13:20
13:25
13:30
13:35
Time
Settled Temp.
Under Precip.
Initial Temp.
Pour
Freeze
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Charts\March13\Chamber Temperature Profiles

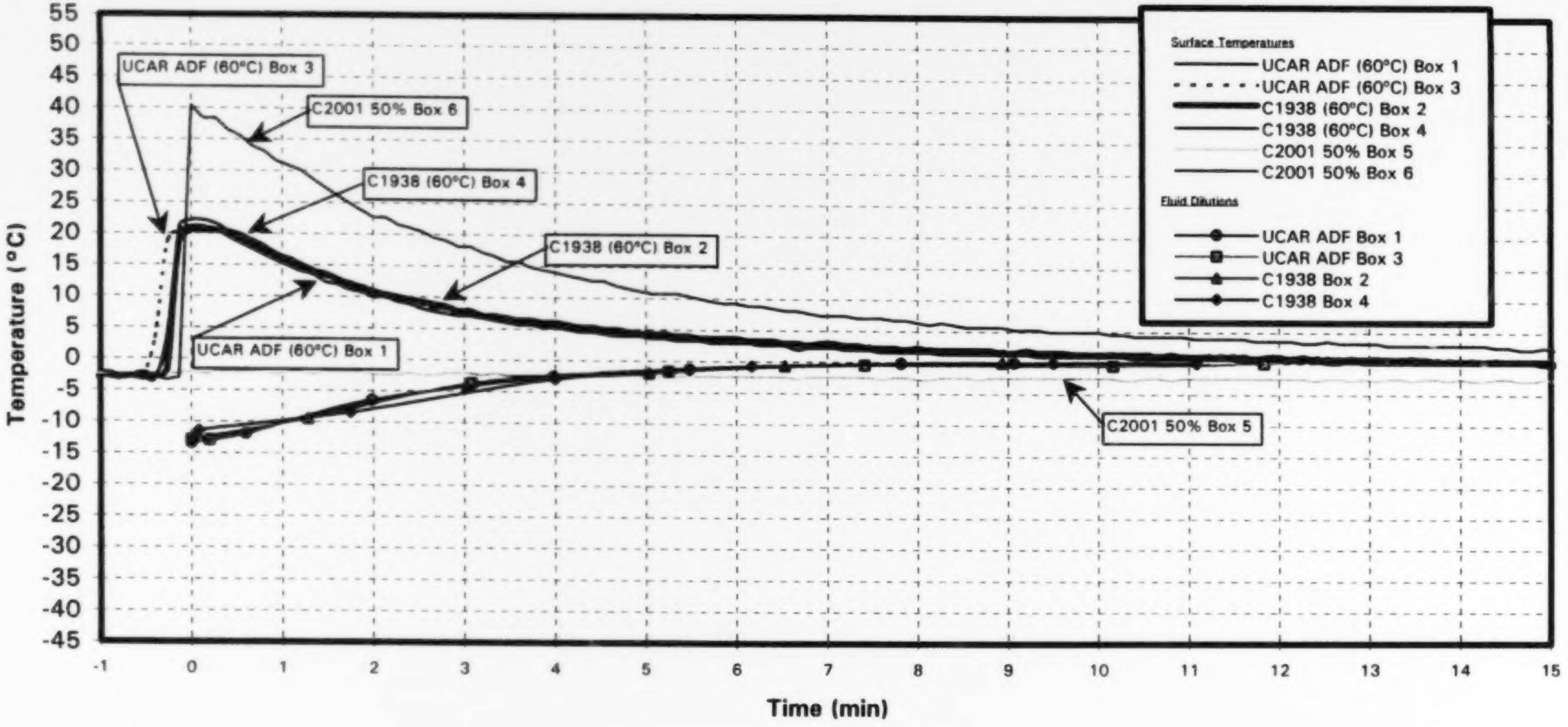
Plate Temperature Profiles
ZD, -3°C, 5 g/dm²/h



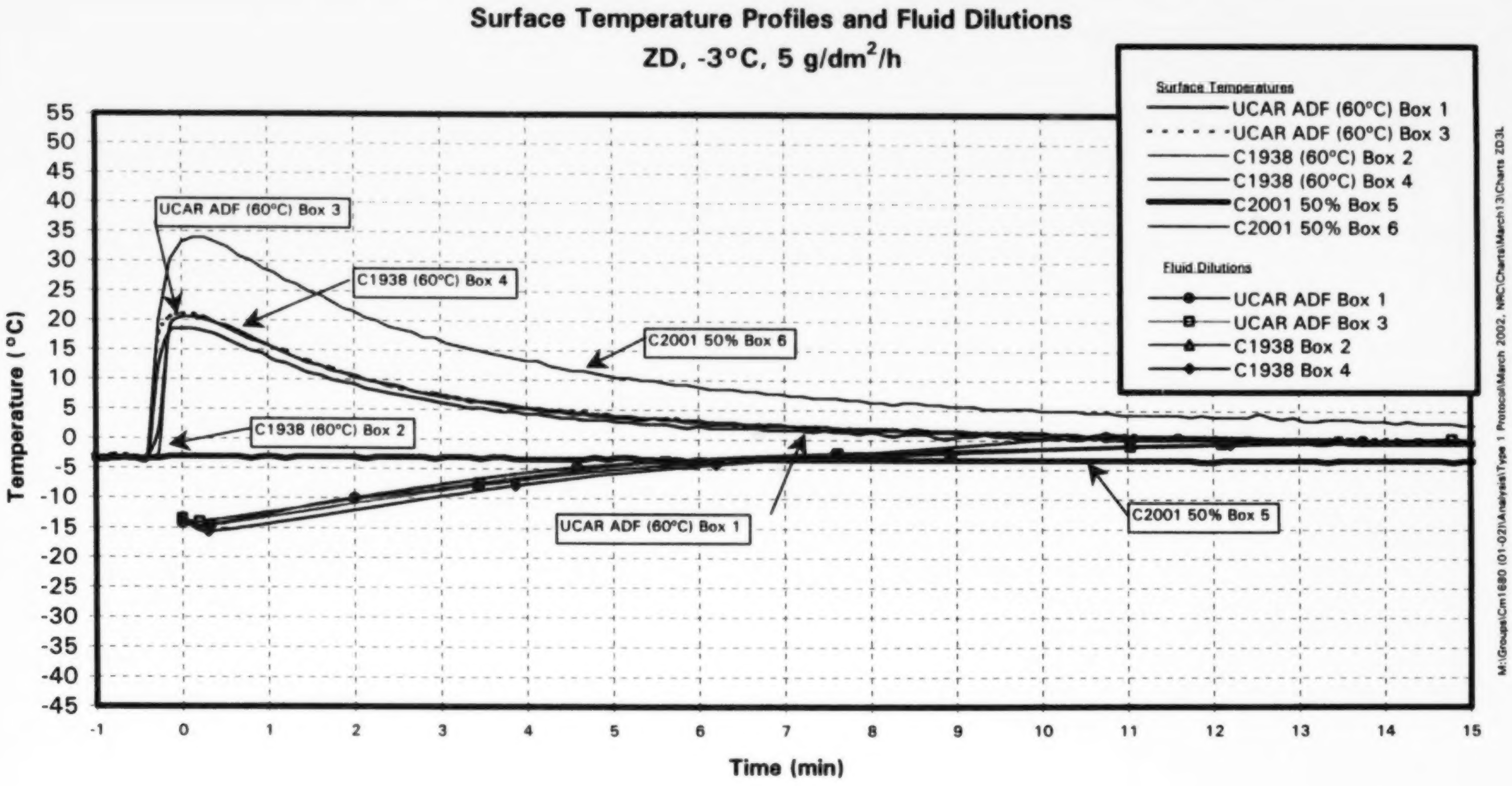
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Charts\March 13\Chamber Temperature Profiles

Surface Temperature Profiles and Fluid Dilutions

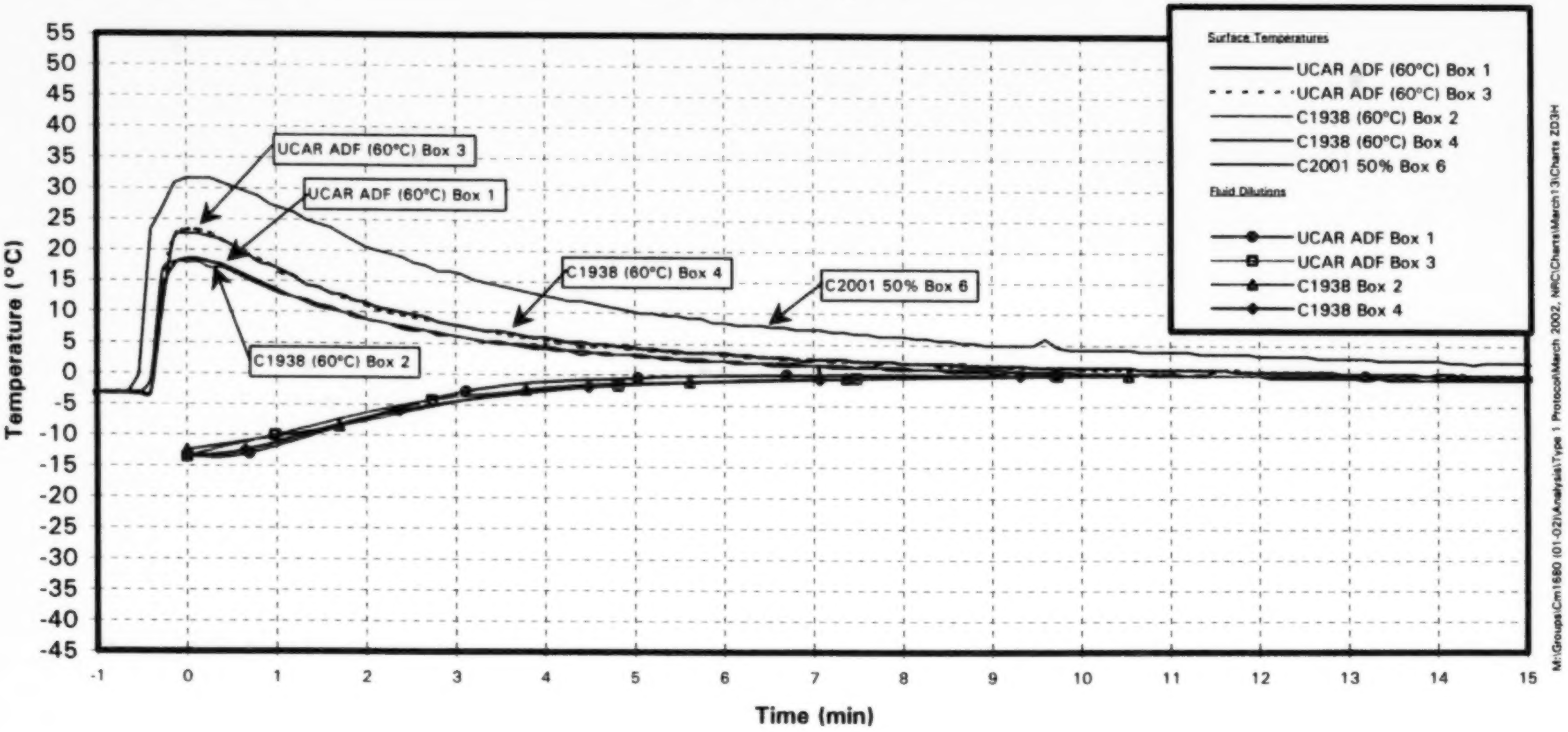
ZR, -3°C, 13 g/dm^2/h



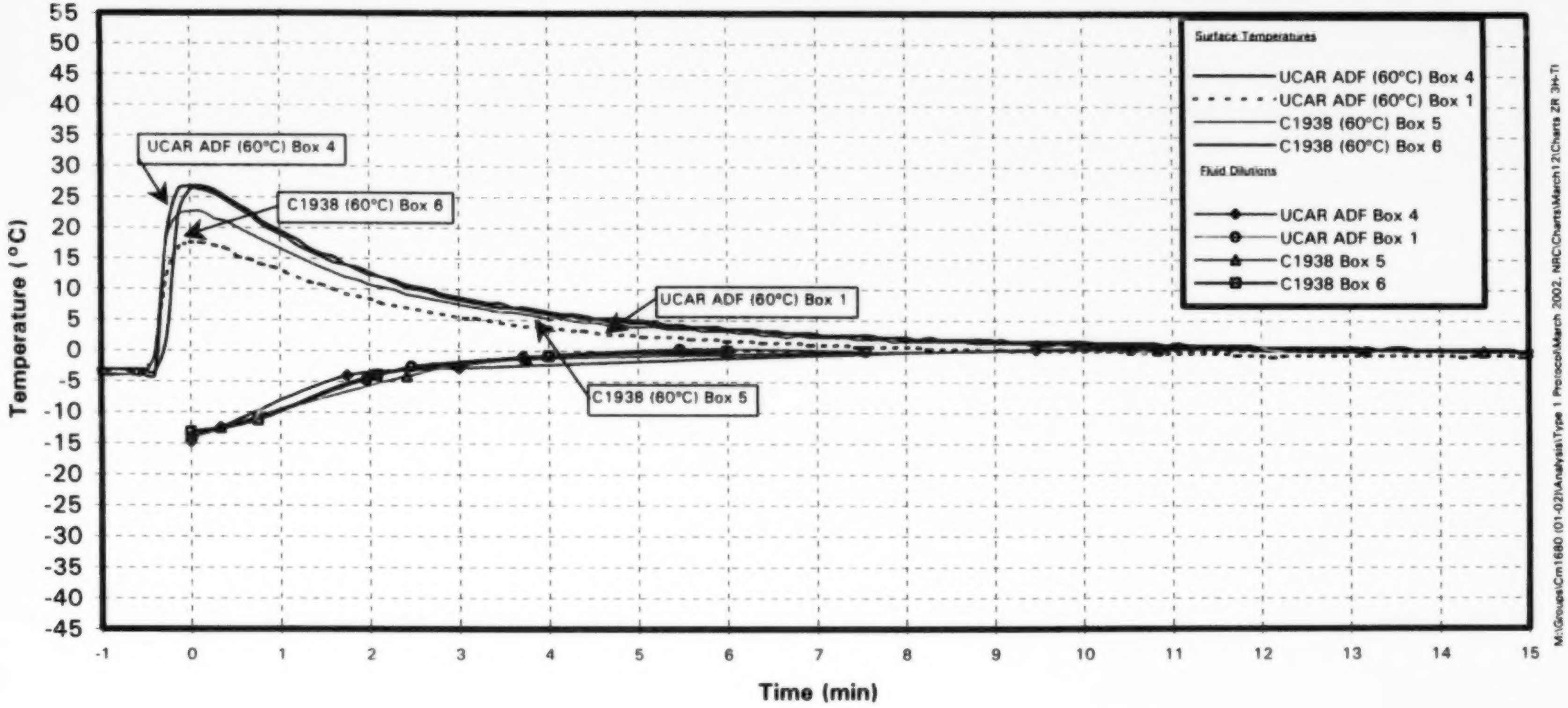
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002. NRC\Charts\March13\Charts ZR3L

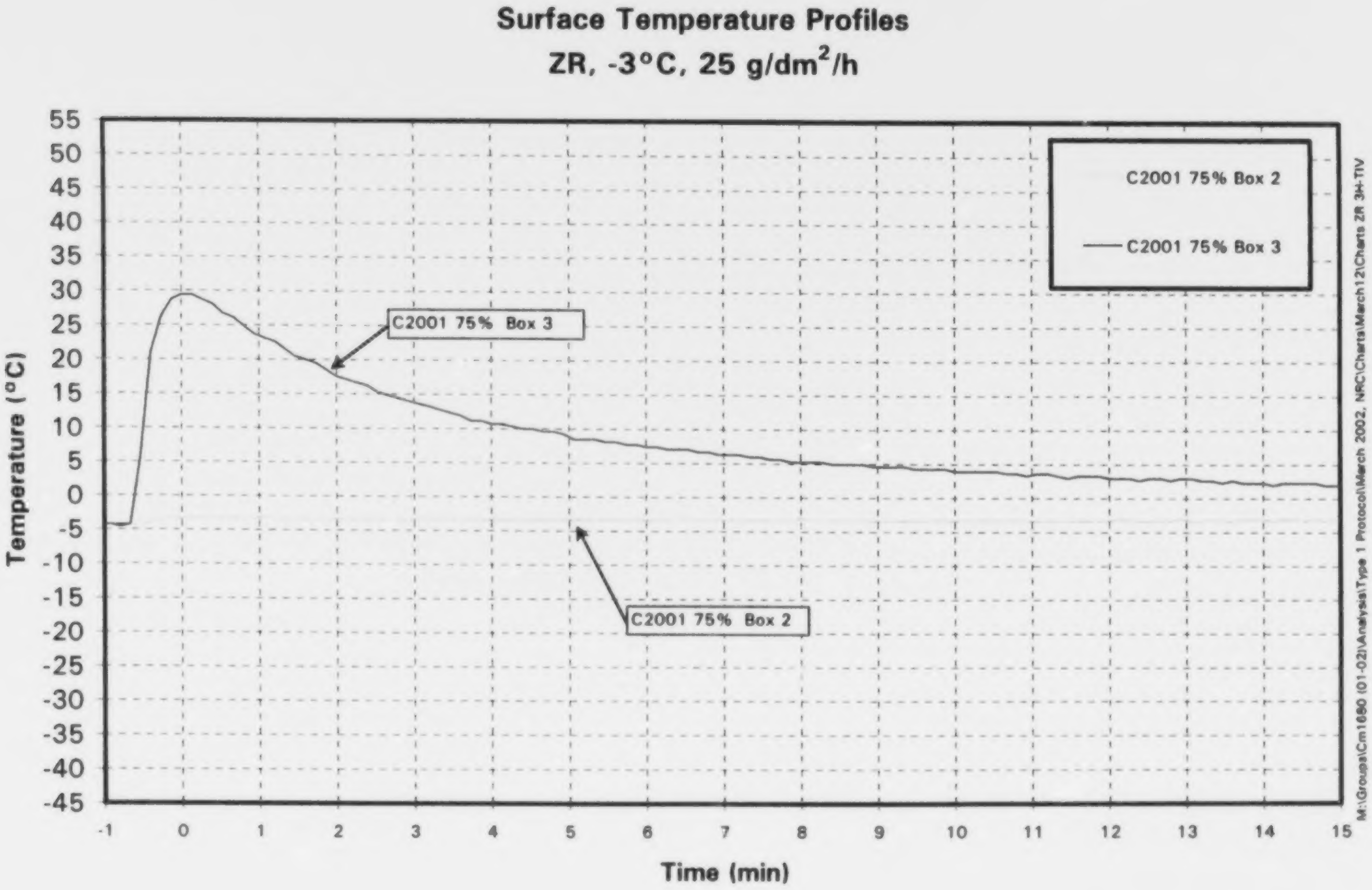

Surface Temperature Profiles and Fluid Dilutions
ZD, -3°C, 5 g/dm²/h
Surface Temperatures
UCAR ADF (60°C) Box 1
UCAR ADF (60°C) Box 3
C1938 (60°C) Box 2
C1938 (60°C) Box 4
C2001 50% Box 5
C2001 50% Box 6
Fluid Dilutions
UCAR ADF Box 1
UCAR ADF Box 3
C1938 Box 2
C1938 Box 4
UCAR ADF (60°C) Box 3
C1938 (60°C) Box 4
C2001 50% Box 6
C1938 (60°C) Box 2
UCAR ADF (60°C) Box 1
C2001 50% Box 5
Temperature (°C)
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (min)
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Charts\March13\Charts ZD3L

Surface Temperature Profiles and Fluid Dilutions
ZD, -3°C, 13 g/dm²/h

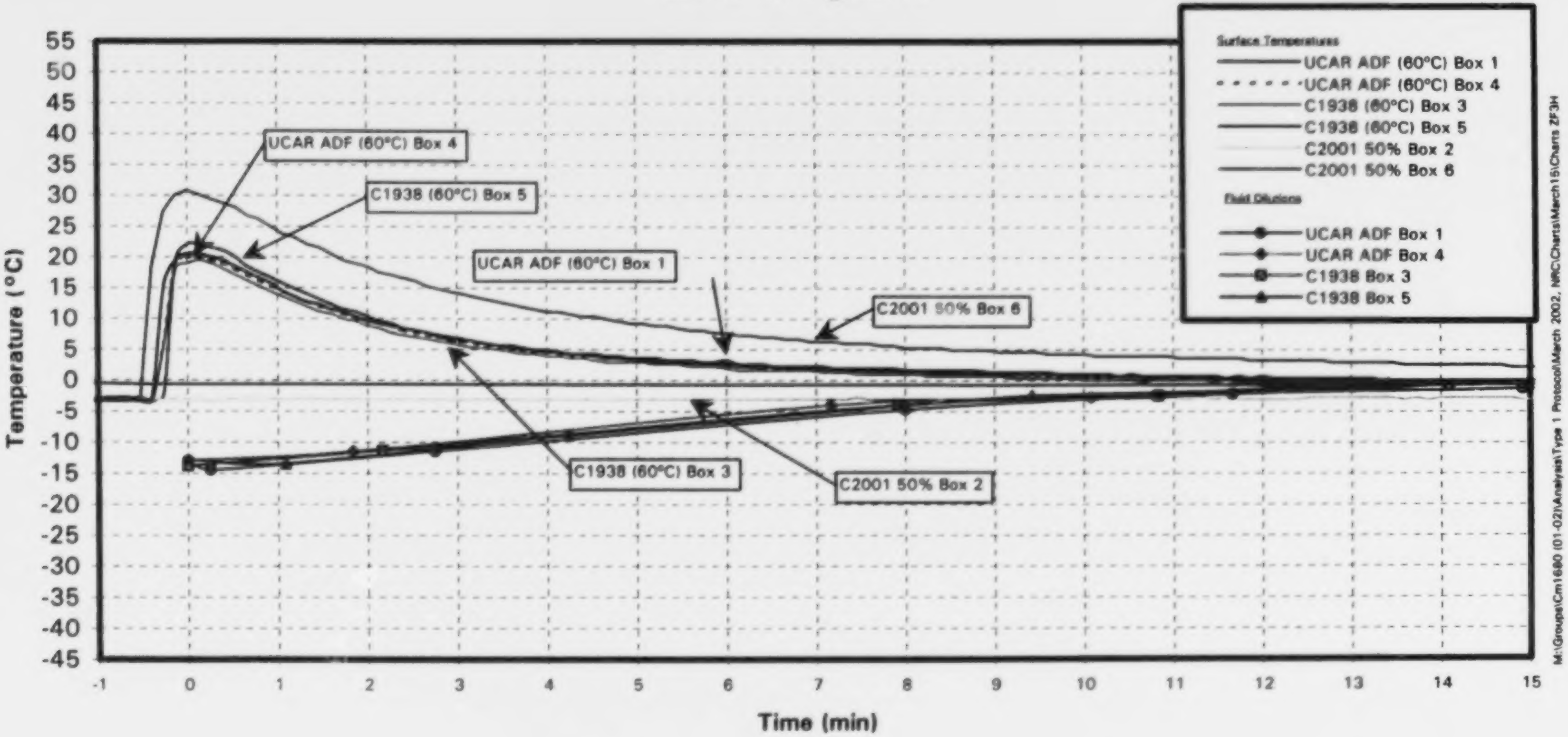


Surface Temperature Profiles and Fluid Dilutions
ZR, -3°C, 25 g/dm²/h

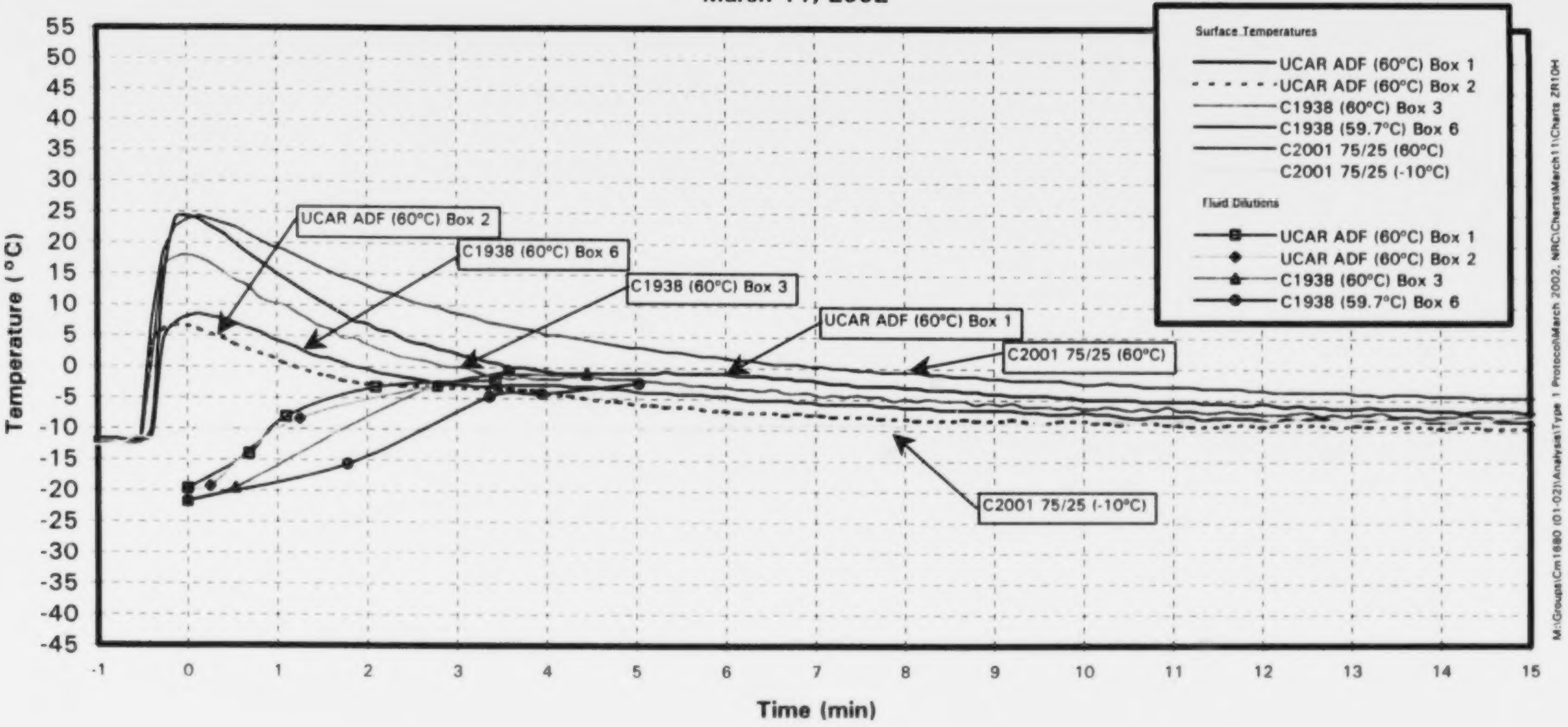




M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Charts\March12\Charts ZR 3H-TIV



Surface Temperature Profiles and Fluid Dilutions
ZF, -3°C, 5 g/dm²/h

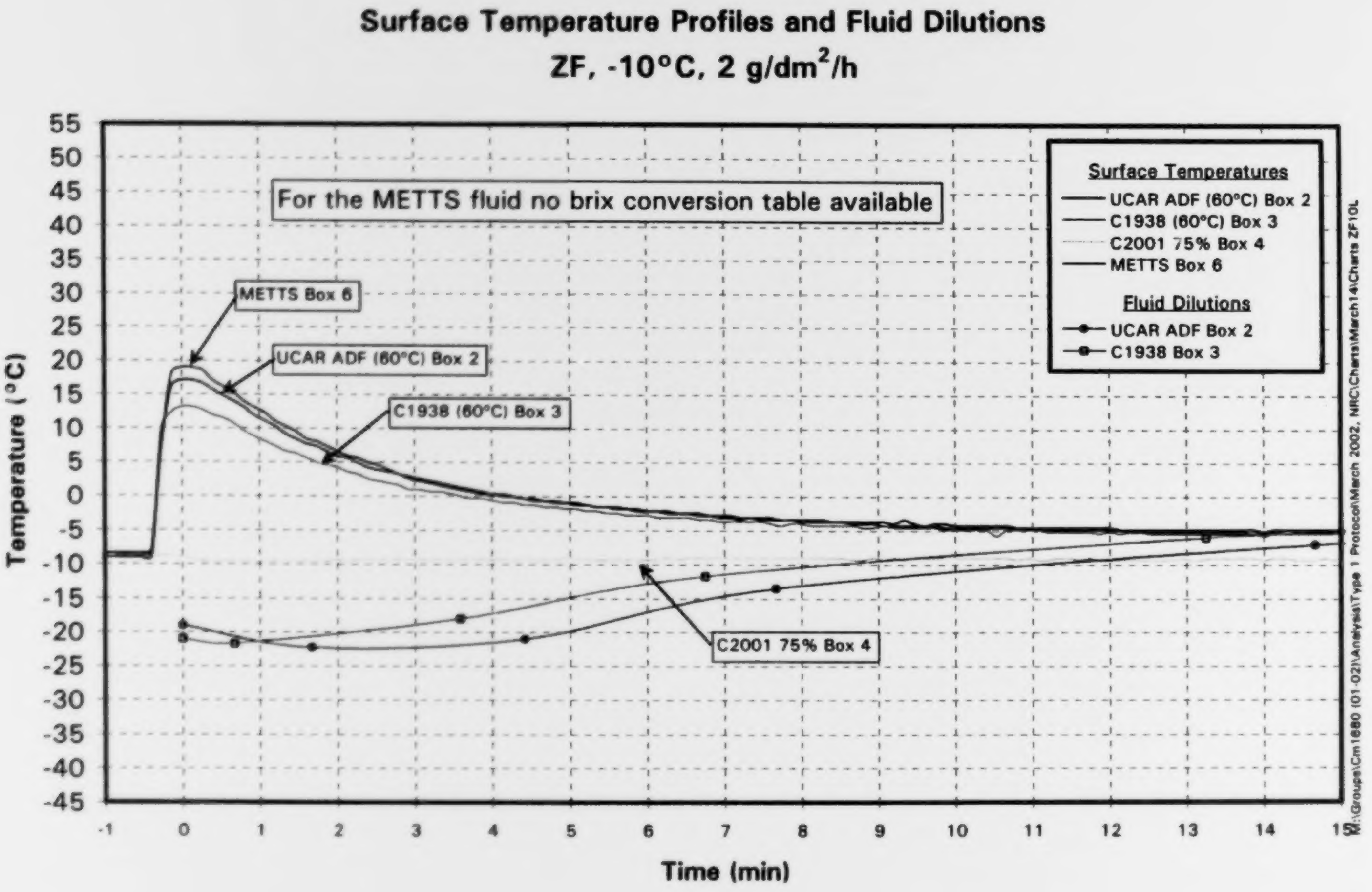


Surface Temperature Profiles and Fluid Dilutions

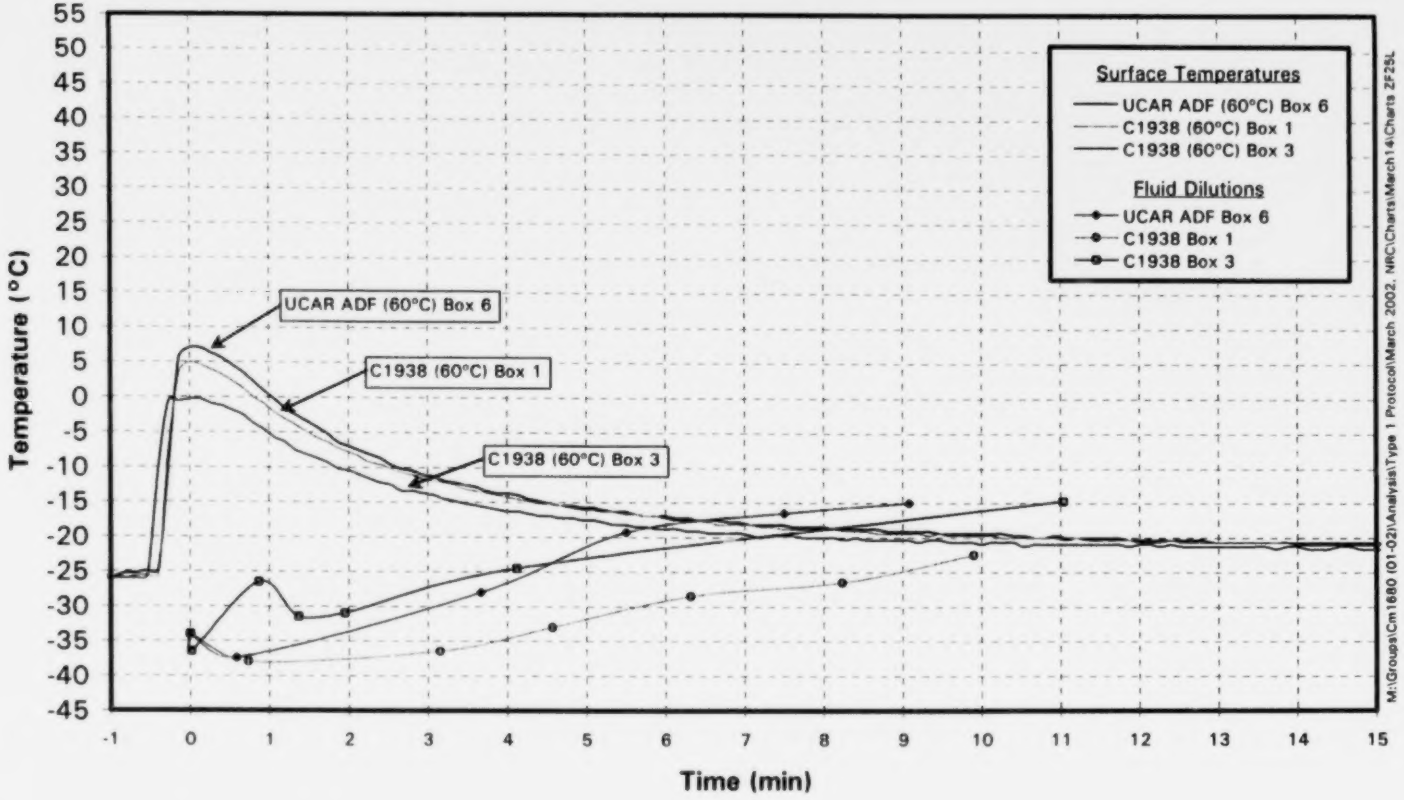
ZR, -10°C, 25 g/dm²/h

March 11, 2002

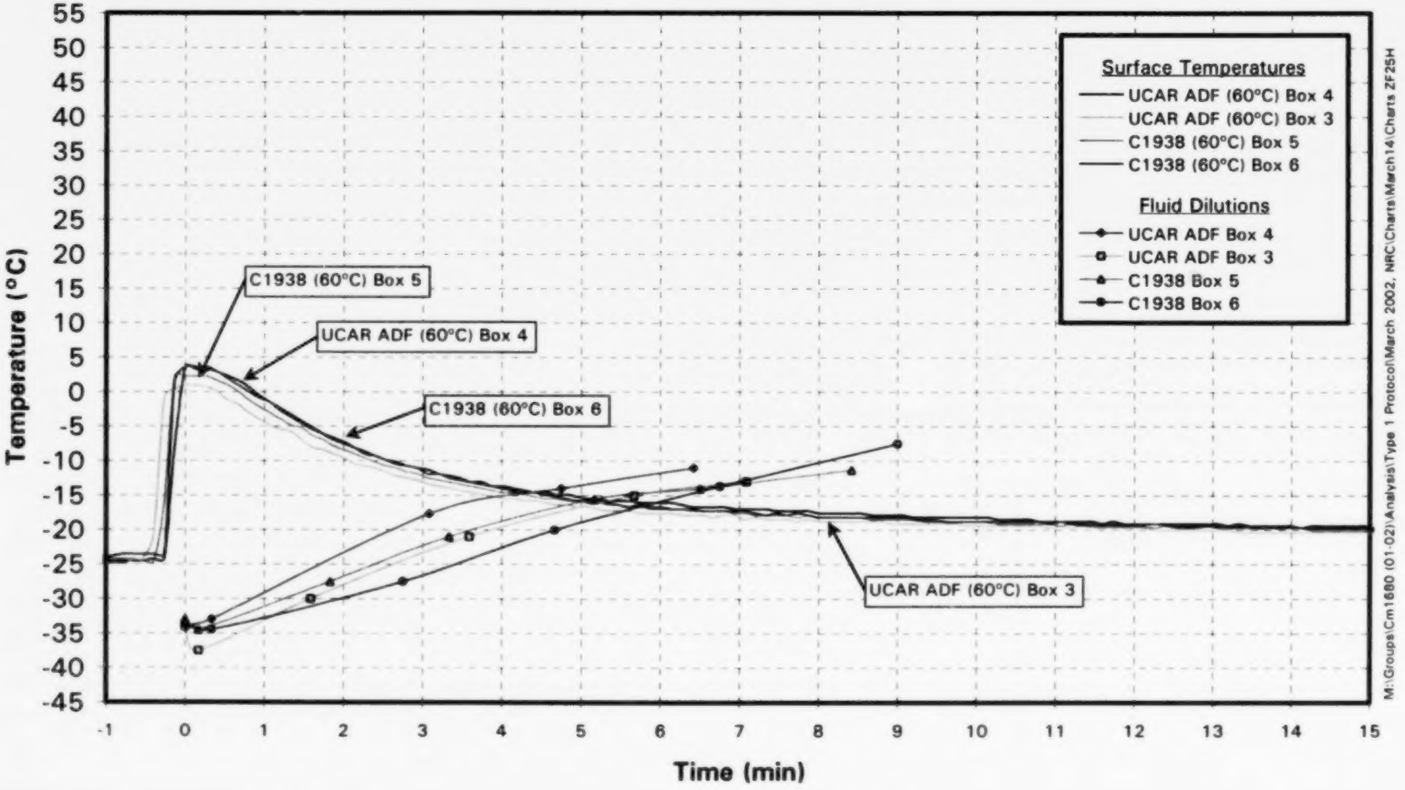
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Charts\March11\Charts ZR10H

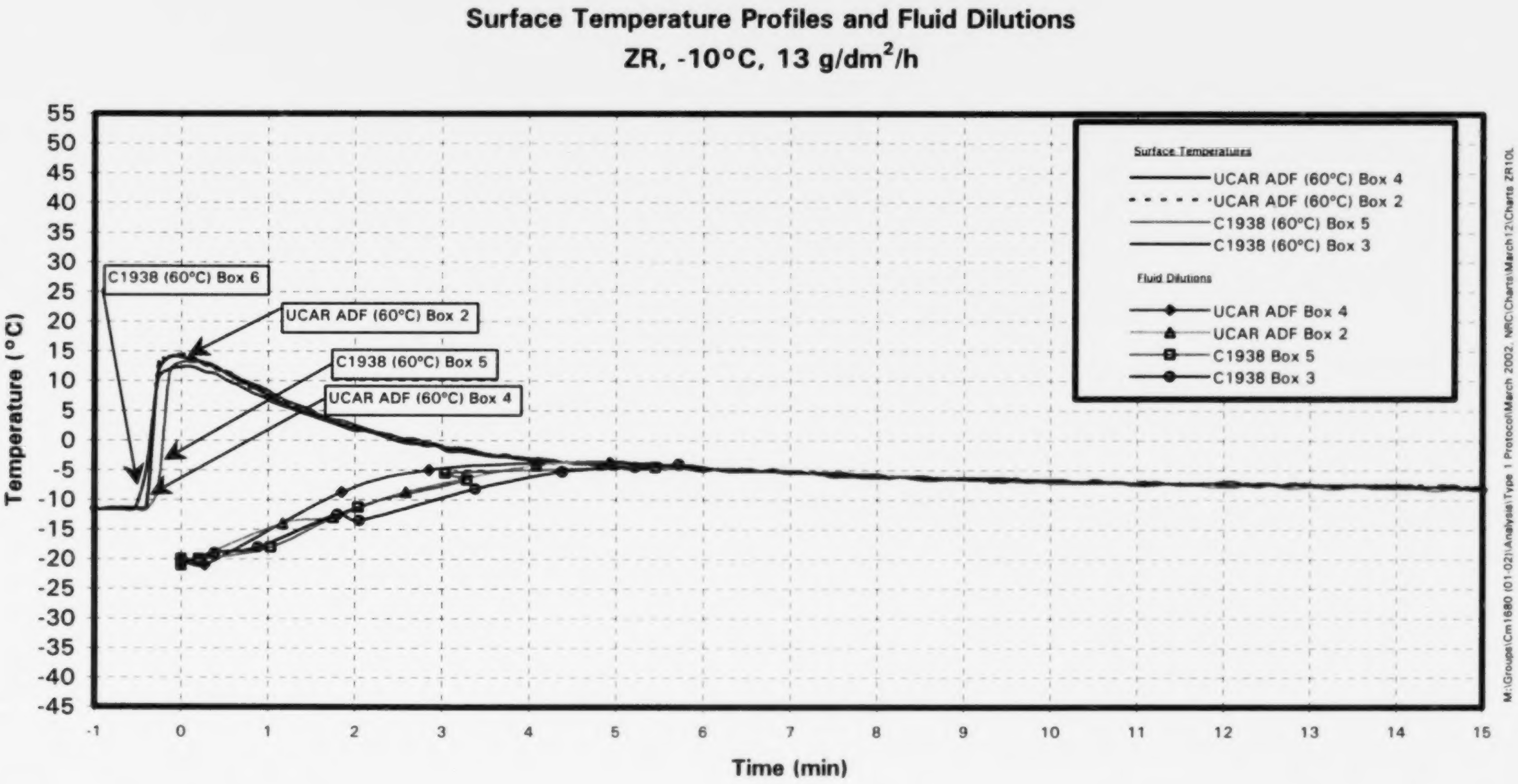

Surface Temperature Profiles and Fluid Dilutions
ZF, -10°C, 2 g/dm²/h
For the METTS fluid no brix conversion table available
Surface Temperatures
UCAR ADF (60°C) Box 2
C1938 (60°C) Box 3
C2001 75% Box 4
METTS Box 6
Fluid Dilutions
UCAR ADF Box 2
C1938 Box 3
METTS Box 6
UCAR ADF (60°C) Box 2
C1938 (60°C) Box 3
C2001 75% Box 4
Temperature (°C)
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Time (min)
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\March 2002, NRC\Charts\March14\Charts ZF10L

Surface Temperature Profiles and Fluid Dilutions
ZF, -25°C, 2 g/dm²/h

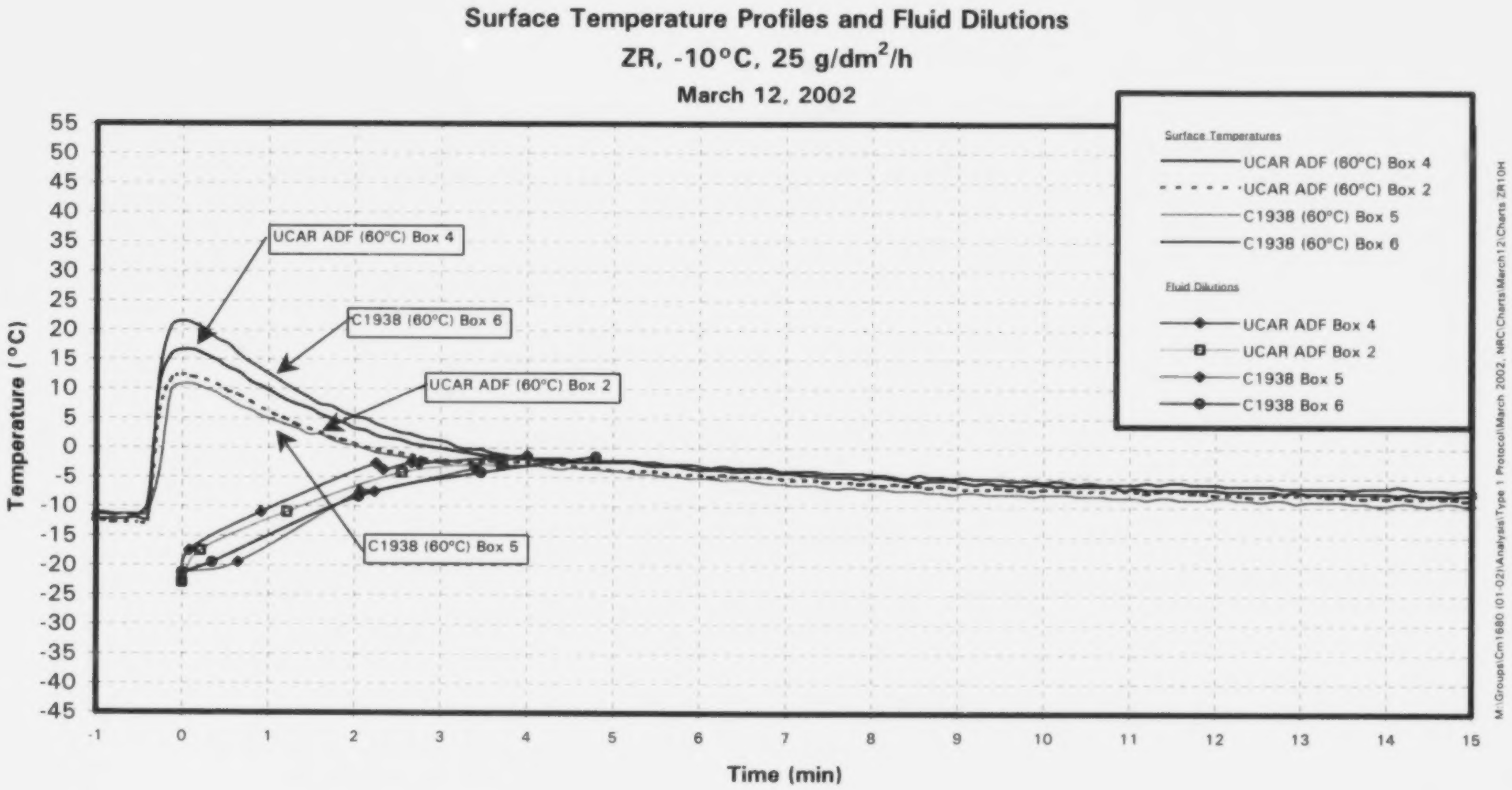


Surface Temperature Profiles and Fluid Dilutions
ZF, -25°C, 5 g/dm²/h

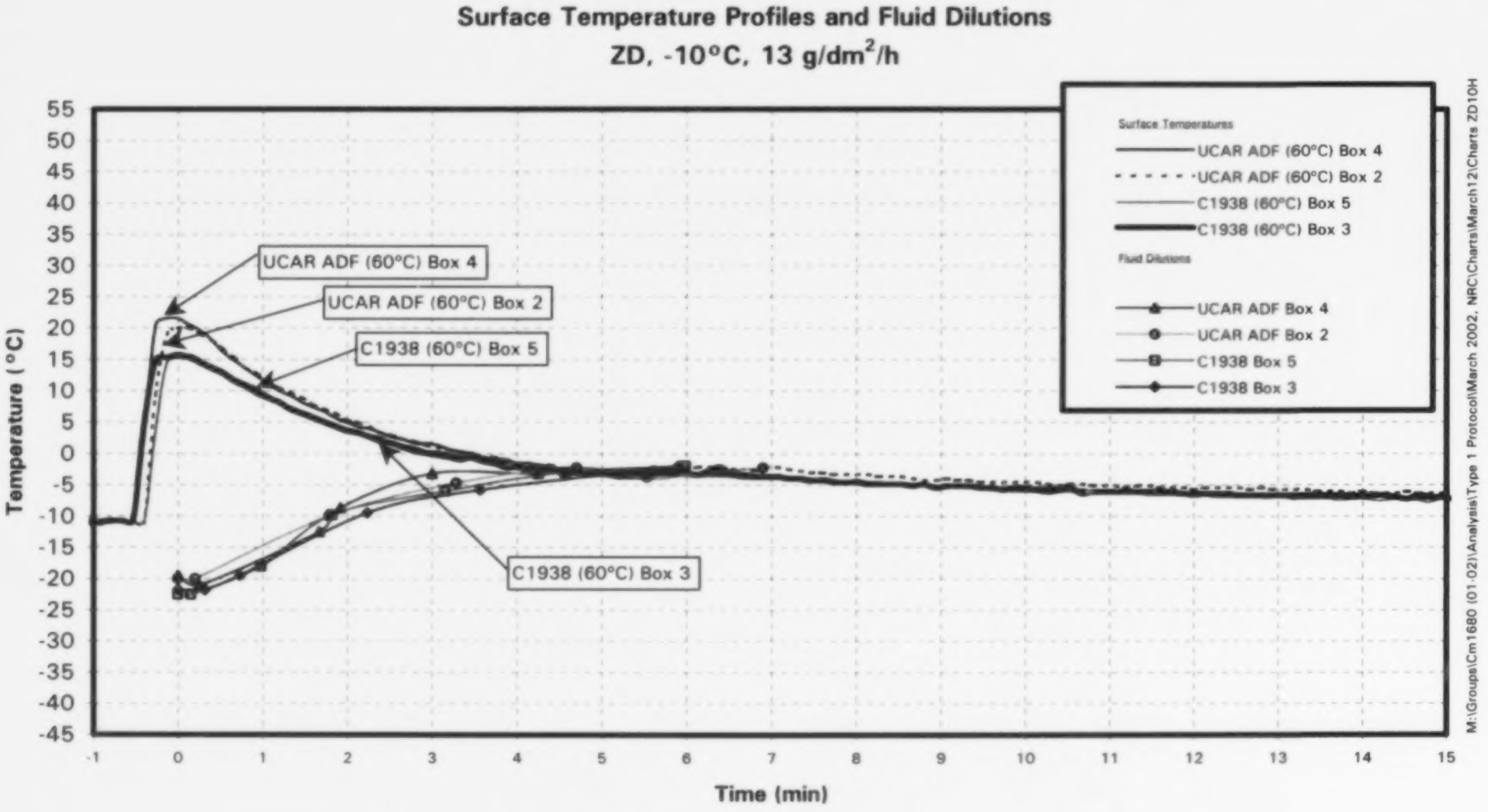




Surface Temperature Profiles and Fluid Dilutions
ZR, -10°C, 13 g/dm²/h



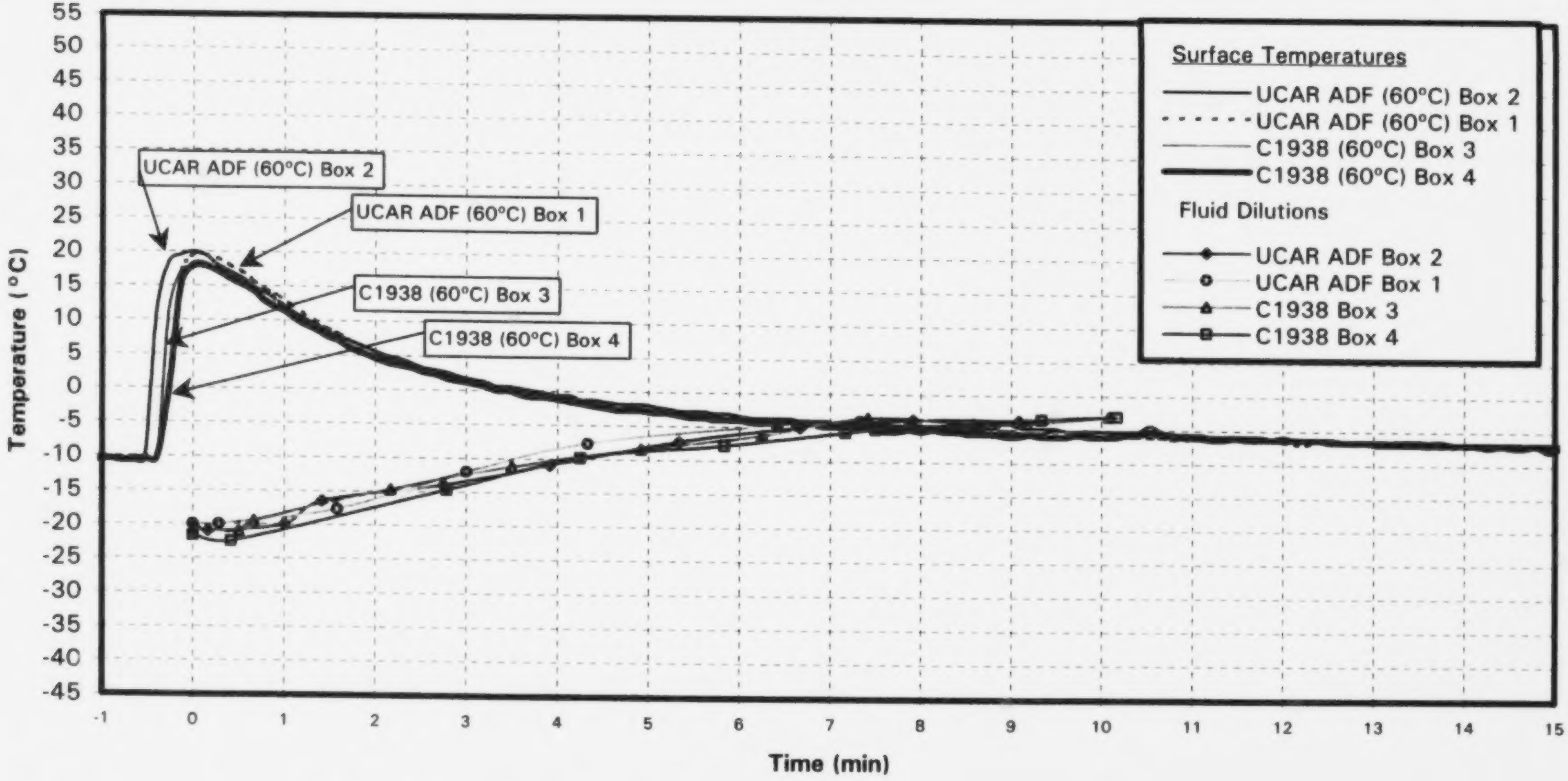
Surface Temperature Profiles and Fluid Dilutions
ZR, -10°C, 25 g/dm^2/h
March 12, 2002



Surface Temperature Profiles and Fluid Dilutions

ZD, -10°C, 13 g/dm²/h

Surface Temperature Profiles and Fluid Dilutions
ZD, -10°C, 5 g/dm^2/h



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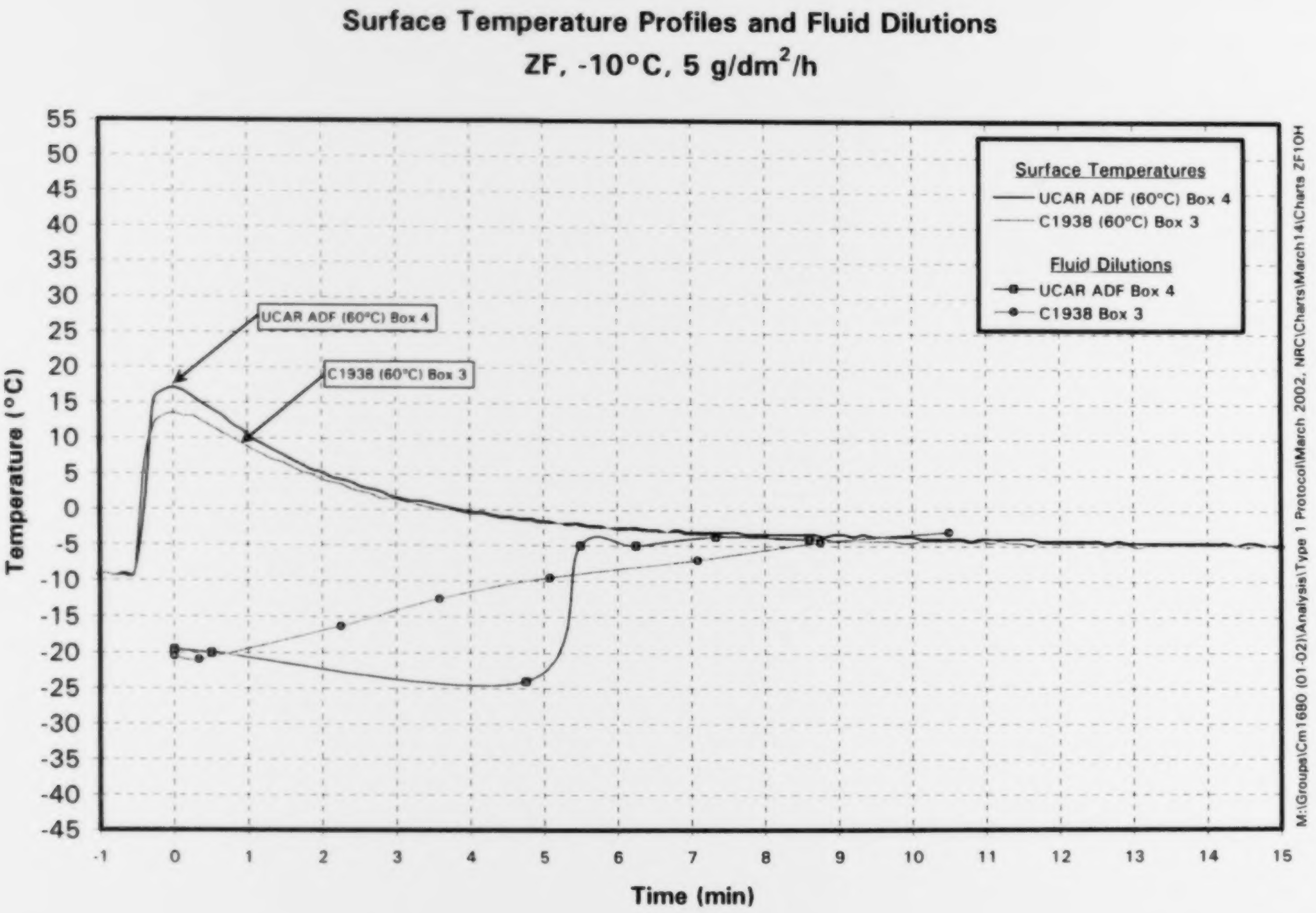


Surface Temperature Profiles and Fluid Dilutions
ZF, -10°C, 5 g/dm²/h

G

APPENDIX G

FIELD TRIALS TO OBTAIN WING AND TEST SURFACE TEMPERATURE PROFILES

- PROCEDURE
- RESULTS

CM1680.001

EXPERIMENTAL PROGRAM
FIELD TRIALS FOR TYPE I HOT TEST PROTOCOL

Winter 2001-2002

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Peter Dawson

Reviewed by: John D'Avirro

APS AVIATION INC. APS

21 November 2001
Version 1.0

EXPERIMENTAL PROGRAM
FIELD TRIALS FOR TYPE I HOT TEST PROTOCOL
Winter 2001-2002

1. OBJECTIVES

To compare fluid endurance times produced by the proposed test protocol for outdoor trials to fluid endurance times experienced on aircraft wing surfaces, in field conditions during natural precipitation.

1.1 Background

A study was conducted during the Winter 2000-2001 to support development of a test protocol to measure endurance times for SAE Type I fluids. The test protocol was to reflect real field operations and in particular, take account of the contribution to endurance times of the heat transferred from the heated fluid to the wing surface.

The study concluded that two test protocols are required, one for outdoor trials in natural precipitation and wind conditions, and a second for laboratory trials in artificial precipitation and calm conditions.

The recommended test procedure for outdoor trials included:

- A test surface consisting of a 7.5 cm cold-soak box, empty of fluid.
- Application of 0.5 L of test fluid, heated to 60°C.
- Application of test fluid using a spreader with a defined rate of draining.

Measurement of the temperature decay rate for the recommended test surface and fluid application procedure showed that this combination produced a temperature decay rate profile (in outdoor conditions with natural wind) very similar to that produced by aircraft wing leading edges when subjected to an application of heated fluid.

This test is designed to compare endurance times produced by the recommended test surface and fluid application procedure, to times produced by Type I deicing of wings of operational aircraft, during natural snow conditions.

1.2 Satisfying the Objective

Simultaneous trials on aircraft and test surfaces will be conducted. The cold-soak box surface and the current flat plate test surface will be mounted on a test stand positioned near the test aircraft, and subjected to the same natural precipitation and wind as the aircraft wing. The test surfaces will be treated with SAE Type I fluid according to the recommended test procedure as well as the previous Type I test procedure, while the aircraft is undergoing deicing in accordance with standard deicing procedures. Fluid endurance times, surface temperature profiles and fluid dilution rates will be measured and compared.

2. PROCEDURE/TEST REQUIREMENTS

Simultaneous trials on aircraft and test surfaces will be conducted on two occasions in natural precipitation. One trial session is planned to be conducted on a Boeing 737 aircraft, provided by US Airways, and on a Saab 340 aircraft provided by American Eagle.

Simultaneous tests will be conducted on the JetStar test wing, which will be parked in a position convenient for testing.

Desired weather conditions for the trials are:

- Medium to heavy snowfall.
- OAT in the range of -5 to -15°C.
- Wind speeds in the range of 15 to 25 km/h.

Fluids will be tested at two concentrations; mixed to a fluid freeze point buffer of 10°C, and at full operational strength.

Trials on the aircraft will incorporate the effect of the removal of contamination, by allowing snow to accumulate on aircraft surfaces between test runs. The spray operator, who will be instructed to spray according to standard procedure, will control the quantity of fluid sprayed. The fluid temperature will be in accordance with standard operating practice (fluid tank temperature of 80°C).

The JetStar test wing is included in the test to examine how fluid endurance on its surface compares to operational aircraft.

Trials on the test surfaces will follow a procedure described later in this document.

Data collected from the trials will include:

- Fluid temperature, quantity and initial strength.
- Ambient conditions; OAT, wind speed, precipitation rate.
- Aircraft fuel; quantity in tanks and temperature.

- Depth of contamination on wing at start of test.
- Temperature profiles of wing and test surfaces.
- Fluid freeze point profile of fluid on the wing and on a test surface.
- Failure times and patterns on wing and on test surfaces.

Previous field studies examining fluid failures on aircraft concluded that the wing leading edge and rear flight control surfaces are the earliest surfaces to experience fluid failure. Because contamination on the leading edge can severely degrade airfoil, wing and take-off performance, this study will give primary attention to fluid condition on the leading edge.

A proposed test matrix for the tests on the aircraft wing is given in Table G-1. Attachment G-1 describes test procedures on the wing and the simultaneous tests on test surfaces.

3. EQUIPMENT

A list of equipment is given in Attachment G-II.

Two deicing vehicles will be required; one for dilute fluid, and one for standard strength.

US Airways has offered to provide a B737 aircraft. American Eagle has offered to provide a Saab340.

Simultaneous tests will be conducted with the JetStar test wing.

4. FLUIDS

SAE Type I ethylene glycol-based fluid (UCAR ADF) will be used. Fluid concentrations will be diluted to a fluid freeze point buffer of 10°C and standard operating mix (50/50).

Fluids will be heated to a tank temperature in accordance with the standard operating procedure followed by Aéromag 2000.

5. PERSONNEL

Ten APS personnel are required for these tests as follows:

At the aircraft:
- leading edge observer
- wing observer
- lead brix sampler
- JetStar test wing observer

At the test stand:
- test surface observer
- assistant brix sampler and fluid preparation
- meteo recorder

Other
- photo
- video
- coordinator.

Attachment G-III lists task assignments.

Aéromag 2000 will perform the aircraft spraying.

6. DATA FORMS

Figure G-1	Equipment Position
Figure G-2 – B737	Thermistor probe locations for B737 Wing
Figure G-2 – Saab340	Thermistor probe locations for Saab340 Wing
Figure G-2 – JetStar test wing	Thermistor probe locations for JetStar test wing
Figure G-3	General Form (Once per Session)
Figure G-4	General Form (Every test)
Figure G-5 – B737 Port	Fluid Failure Form for Leading Edge and Wing
Figure G-5 – B737 Stbd	Fluid Failure Form for Leading Edge and Wing
Figure G-5 – Saab340 Port	Fluid Failure Form for Leading Edge and Wing
Figure G-5 – Saab340 Stbd	Fluid Failure Form for Leading Edge and Wing
Figure G-5 – JetStar test wing	Fluid Failure Form for Leading Edge and Wing
Figure G-6 – B737	Brix Form for B737 Wing and Test Surfaces
Figure G-6 – Saab340	Brix Form for Saab340 Wing and Test Surfaces
Figure G-6 – JetStar test wing	Brix Form for JetStar test wing and Test Surfaces
Figure G-7	End Condition Data Form
Figure G-8 – B737	Failed Fluid Roughness Form for B737
Figure G-8 – Saab340	Failed Fluid Roughness Form for Saab340
Figure G-8 – JetStar test wing	Failed Fluid Roughness Form for JetStar test wing
Figure G-9	Meteo/Plate Pan Data Form – Type I protocol

TABLE G-1
TEST PLAN
FIELD TRIALS FOR TYPE I HOT TEST PROTOCOL

TEST SESSION	RUN	AIRCRAFT TYPE	OAT (°C)	FLUID FREEZE POINT (°C)	FLUID TEMP (°C)	FLUID QUANTITY (L)	SNOW DEPTH ON WING (cm)
1	1	B 737	-5 to -15	OAT – 10°C	As sprayed	As sprayed	>1cm
1	2	B 737	-5 to -15	OAT – 10°C	As sprayed	As sprayed	>1cm
1	3	B 737	-5 to -15	Full strength	As sprayed	As sprayed	>1cm
2	4	Saab 340	-5 to -15	OAT – 10°C	As sprayed	As sprayed	>1cm
2	5	Saab 340	-5 to -15	OAT – 10°C	As sprayed	As sprayed	>1cm
2	6	Saab 340	-5 to -15	Full strength	As sprayed	As sprayed	>1cm
1,2	1,4	JetStar test wing	-5 to -15	OAT – 10°C	As sprayed	As sprayed	>1cm
1,2	2,5	JetStar test wing	-5 to -15	OAT – 10°C	As sprayed	As sprayed	>1cm
1,2	3,6	JetStar test wing	-5 to -15	Full strength	As sprayed	As sprayed	>1cm

Note: these test runs will be repeated during the test session if additional information can be collected, for example, due to a change in ambient conditions.

Attachment G-I describes the procedure for these tests, and the simultaneous tests conducted on test surfaces.

ATTACHMENT G-I

TEST PROCEDURES
FIELD TRIALS FOR TYPE I HOT TEST PROTOCOL

PRE-TEST SETUP

- Brief team members on test procedure and individual assignments. Distribute data forms.
- Synchronise all timepieces, loggers and cameras with atomic clock.
- Prepare fluids for testing on test surfaces.
- Brief Aéromag on procedure. Discuss fluid mix and temperature requirements.
- Ensure all cameras are functional.
- Park the aircraft, nose into the wind.
- Park the JetStar test wing off the end of the aircraft wing, as an extension.
- Record fuel load in test wing.
- Arrange equipment around the aircraft in accordance with Figure G-1.
- Set-up mobile light unit. Ensure adequate illumination of wings.
- Set-up generators and power cords.
- Set-up stairs near the wing.
- Install thermistor probes on the wing in accordance with Figure G-2.
- Set-up the test-stand with test surfaces and thermistor probes installed. Position test stand into the wind.
- Set-up data logger; test thermistor probes for function. Make note of which logger channel represents which test surface and wing location.
- Position cube van to support precipitation-rate measurement.
    - Set-up rate station table, scale, lights in van.
    - Set-up fluid preparation station.
    - Set-up thermistor laptop for logger display.
- Position second cube van for personnel use.

TESTS ON AIRCRAFT AND JETSTAR TEST WING

For Each Run

- Measure truck tank fluid Brix and temperature.
- Measure depth of snow coverage on wings prior to spray.
- Videotape entire fluid spray from an appropriate vantage point.
- Measure fluid temperature at nozzle, spraying away from wing. Spray enough to clear the lines of cold fluid.
- Deice the aircraft wing and then the JetStar test wing. Record amount of fluid applied on each wing.

- Record OAT, wind speed and direction.
- Photograph and videotape the test setup. Ensure that locations of thermistor probe installations on wing surface are recorded.

Observe Time to Freeze and record failure pattern

- Observe wing leading edge for first freezing and record on the wing form. Disregard any early freezing caused by the sampling activity. Thereafter, record failure pattern on the leading edge when advised by the test surface observer at the following events:
    - at failure call of the standard HOT plate
    - at failure call of the 7.5cm cold-soak box surface
    - If the time interval before or between any of the failure events is longer than 5 minutes, make additional records of failure pattern. Depending on leading edge condition following all test surface events, continue at 5-minute intervals until the leading edge is at least 25% failed.
- Photograph and videotape the leading edge condition when the fluid failure patterns are being recorded.
- Measure fluid strength on the wing at the specified locations. Ensure sampled locations are shifted each time to avoid repeat sampling at the same point. Protect the fluid sample from precipitation.
- Measure and record roughness profiles, adhesion and distribution of failed areas, and changes in these parameters with time, following failure call.

Prepare for Next Test

- Allow sufficient time for wing to cool to ambient temperature, and for snow to re-form on wing surfaces (at least 1 cm deep).

End of Test Session

- Deice wing.
- Remove thermistor probes from wing, ensuring that no trace of tape remains.

TESTS ON SURFACES

Setup

- Follow standard procedures for HOT tests except as described in the following.
- Prepare surfaces on stand, placed on the top row in accordance with the following table. Ensure all thermistor probes on surfaces are logging temperature.
- Prepare fluid for testing. Fluid strength tested will correspond to that tested on the aircraft (either a 10°C freeze point buffer or standard strength). Each test run will require fluid as shown in the following table.

STAND POSITION	SURFACE TYPE	FLUID			POUR SEQUENCE
		TYPE/ STRENGTH	AMOUNT (L)	TEMP (°C)	
1	Rate Pan				
2	7.5 cm box (empty)	EG/ 10°C buffer or Std	0.5	60	1st
3	7.5 cm box (empty)	PG/ 10°C buffer or Std	0.5	60	2nd
4	Standard plate	EG/ 10°C buffer or Std	1	20	3rd
5	Standard plate	PG/ 10°C buffer or Std	1	20	4th
6	Rate Pan				

- Pour required amount of heated fluid into thermos containers in preparation for application.
- Protect the fluid spreader from cooling.

When aircraft spraying commences:

- Apply fluid on surfaces according to the table. Treat the box surfaces in quick succession to avoid cooling of the spreader between pours. Use the following procedure for cleaning the surface and pouring fluid:
    - Clean the plate of all contamination with scraper and squeegee. Apply a small amount of fluid at ambient temperature and squeegee the plate over its entire surface. This is intended to ensure that the surface is wetted as well as clean, to assist in complete coverage with the applied fluid.
- Shield the plate from wind when pouring the test fluid from the thermos into the spreader. Remove the shield when the spreader has emptied.
- Apply fluid to the standard HOT surface according to the standard method. (clean the plate with scraper and squeegee, pour about 1/3 of the fluid over the plate, squeegee dry, and then pour the remainder of the fluid along the top edge.).
- Determine failure times on test surfaces, and record using standard HOT data forms.

- Conduct precipitation rate measures using the Meteo/Plate data form. Use two rate pans in a staggered routine, exchanging one pan for the other at the time that a measurement is required. Record rates at specific times during the test:
  - at failure call of the standard HOT plate
  - at failure call of the 7.5 cm cold-soak box
  - at failure call on the aircraft leading edge
  - at test end
- Record wind speed at the test stand before and after each run. Measure wind speed by moving along the rear of the stand, with the anemometer held over the rear edge of the test surfaces at a 2 m height above ground.

ATTACHMENT G-II

TEST EQUIPMENT CHECKLIST
FIELD TRIALS FOR TYPE I HOT TEST PROTOCOL

TASK	*STATUS*
Logistics For Every Test	
Monitor Forecast	
Co-ordinate with aircraft provider; arrange for a/c delivery, contact person for a/c overnight, a/c orientation	
Co-ordinate with Aéromag 2000; review truck and fluid needs	
Call Personnel	
Rent 2 cube vans: one for lab, one for personnel	
Rent mast light	
Test Equipment	
General for all Tests	
Security Passes	
Deicing Truck with 10°C buffer fluid	
Deicing truck with standard deicing fluid	
Test procedures	
Data Forms	
Temperature Probe and spare batteries	
Clipboards	
Pencils	
Paper towels	
Electrical extension cables	
Fluid containers for truck fluid sampling	
Temperature Probe for truck fluid at nozzle	
Tools	
Compass	
First aid kit	
Fire extinguisher	
Squeegees	
Large clock	
Preparing Wing	
Rolling Stairs X 6	
Stepladders for JetStar test wing X 4	
Markers, solvent and cloth wipers	

TASK	*STATUS*
Preparing Wing (continued)	
Tape measures X 4 (2 long, 2 short)	
Thermistor probes and cables	
Logger kits	
Laptop PC X 2 (in cube van)	
Table for laptop in van	
Speed Tape	
Heat gun	
Rubbing alcohol	
Marker	
Pylons	
Stepladder X 2	
Wing Observers	
Brixometers X 2	
Large clock	
Whistle	
Depth gauges and scale to measure snow depth	
Forensic scales for roughness measures	
Test surface observers	
Test stand (1 x 6)	
Test surfaces: 7.5 cm cold-soak box (empty) X 2	
Standard HOT test plate X 2	
Brixometer	
Scrapers and squeegees	
Wiper rags	
Wind shield	
Type I Fluid spreaders	
Preparing Fluids for Test Stand	
Table in cube van	
Heating pots	
Hot plates	
Generator and cable	
Fluid thermometer	
Vacuum bottles and rack	
Heated Type 1 EG fluid (from truck)	
Cold Type 1 EG fluid for blending temperature	
Type I PG fluid	

TASK	*STATUS*
Meteo	
Rate pans X 4	
Light for cube van	
Table	
Scale; 2 g accuracy	
Laptop PC for rates	
Generator	
Fuel for Generator	
Vaisala RH meter	
Wind gauge	
Camera Equipment	
Digital Video Camera	
Still Camera and film	
Video Camera	
Digital still camera	

ATTACHMENT G-III

RESPONSIBILITIES/DUTIES OF TEST PERSONNEL FIELD TRIALS FOR TYPE I HOT TEST PROTOCOL

Team leader (1)

- Complete data form Figure G-3
- Monitor weather, and initiate test with Airline providing aircraft for test, Aéromag, TDC, and FAA.
- Advise APS test team
- Ensure that all required equipment is available and functional.
- Brief all involved on test procedure and assignments.
- Co-ordinate delivery of aircraft to Central Deicing Facility; advise re parking orientation.
- Ensure that all data are collected and saved, and that all test records are submitted.
- Ensure that all personnel are aware of safety issues (Attachment G-IV).

Photo (1)

- Ensure camera is recording time-stamp.
- Photograph all test set-up. The record is to include location of thermistor probes on wing surface.
- Photograph freezing pattern on leading edge when the leading edge observer is recording failure patterns.
- Photograph freezing pattern on test surfaces following failure call.
- Photograph roughness of iced areas following failure call, as directed by leading edge observer.
- Assist in test set-up and take-down.

Video (1)

- Ensure camera is recording time-stamp.
- Videotape all test set-up. The record is to include location of thermistor probes on wing surface.
- Videotape spraying of aircraft wing and pouring of fluid on test surfaces.
- Videotape freezing pattern on leading edge at the times that the leading edge observer is recording failure patterns.
- Assist in test set-up and take-down.

Leading Edge Observer, Wing Observer (2)

- Confirm assigned position with team leader.
- Install mast light.
- Position stairs at wing

- Working together, install thermistor probes at assigned location.
- Assist in general set-up.
- Ensure all data forms completed and submitted at test end.
- Dismantle thermistor system at end of test session. Ensure no remnants of speed tape are left on wing.
- Clean any markings from wing surface with approved solvent.

Aircraft Wing Leading Edge Observer

- Complete data forms Figures G-5, and G-8.
- Concentrate on observing wing leading edge and leads the activity at the wing. Record time and location of first freezing on the wing leading edge form. Disregard any early freezing caused by Brix sampling. Thereafter, record failure pattern on the leading edge when advised by the test surface observer whistle at the following events:
    - at failure call of the standard HOT plate
    - at failure call of the standard 7.5cm cold-soak box surface
- If the time interval between any of the failure events is longer than 5 minutes, make additional records of failure pattern. Depending on leading edge condition following all test surface events, continue at 5-minute intervals until the leading edge is at least 25% failed.
- Advise the coordinator and meteo when wing leading edge has reached failure.
- Advise the wing observer each time recording is started for the leading edge.
- Call attention of photographer and video to failed areas for recording.
- Following fluid failure call on the leading edge and with the assistance of the photographer, record the roughness profiles, distribution, adhesion, and changes in these parameters with time.
    - Select one or two failed areas on the wing to observe and sketch those areas on a wing diagram.
    - At 5-minute intervals, measure the thickness of the ice in the selected area, and record the maximum and minimum. The forensic scales or a thickness gauge would be used for this. If the ice is adhered, the pin end of a caliper could alternatively be used. Adhesion may be assessed simply by testing the ice for ease of movement, with a pencil.
    - Photograph the area under observation at the 5-minute intervals, keeping the forensic scale in the photo view. The camera time stamp must be operational for this test.

Wing Observer

- Complete data form Figure G-5.
- Concentrate on remainder of the wing, less the leading edge.
    - Record failure patterns on the wing form at the same time that the leading edge observer records.

JetStar Test Wing Observer (1)

- Assist in test set-up and take-down.
- Complete data form Figure G-5.
- Record time and location of first freezing on the wing leading edge form. Disregard any early freezing caused by Brix sampling. Thereafter, record failure pattern on the leading edge when advised by the test surface observer whistle at the following events:
    - at failure call of the standard HOT plate
    - at failure call of the standard 7.5cm cold-soak box surface
- If the time interval between any of the failure events is longer than 5 minutes, make additional records of failure pattern. Depending on leading edge condition following all test surface events, continue at 5-minute intervals until the leading edge is at least 25% failed.

Lead Brix Sampler (1)

- Complete data forms Figures G-4 and G-6.
- Brix Sampler records spray specifics and measures Brix on wing.
    - Work with Aéromag 2000 to prepare fluid in truck for test (type, strength, temperature).
    - Complete the general form for every test, recording specifics on spray and snow depth on wing. Before test, take sample of fluid from truck tank; measure temperature and Brix.
    - Measure fluid temperature at truck nozzle just prior to each fluid application. Measure Brix of truck fluid.
    - Record start and end times, and amount of fluid applied.
- With the help of the Brix assistant, measure Brix on the two test surfaces treated with Type I EG fluid and on the wing at three designated locations. Record on Brix Form. Start by measuring on the test surfaces immediately after fluid application, and then sample at the wing locations. For the test surfaces, stagger consecutive measured positions along the 15 cm line. Circulate continuously between test surfaces and wing, with the objective of completing a circuit every two minutes. Ensure sampled locations are shifted each time to avoid repeat sampling at the same point. Protect the fluid sample from precipitation.

Test Surface Observer (1)

- Complete data form Figure G-7.
- Prepare all equipment for moving from trailer to the CDF.
- Co-ordinate setting up major equipment at the test site.
- Oversee dismantling and orderly return of equipment.
- Set-up stand according to the test procedure.
- Co-ordinate set-up of thermistor logger and Laptop PC. Monitor to ensure all

probes are operating throughout the test session. Enter location description for individual probes. *Save logger data onto PC following each test run.*

- Concentrate on recording fluid failures and leading the activity at the stand.
- When aircraft spraying commences, treat the test surfaces as described in the procedure.
- Alert the leading edge observer and the meteo recorder by blowing the whistle when the following events occur:
    - failure call of the standard HOT plate (EG fluid)
    - failure call of the 7.5cm cold-soak box surface (EG fluid).

Assistant Brix Sampler (1)

- Set-up test-surface-fluid preparation station and prepare fluids for application. Assist in pouring.
- Assist the lead brix sampler in measuring and recording brix, on the test surfaces and wing.

Meteo Recorder (1)

- Completes data form Figure G-9.
- Set-up equipment for measuring precipitation rate.
- Assist in pouring fluid on test surfaces.
- Conduct precipitation rate measures using the Meteo/Plate data form Figure 9. Use two rate pans for each pan position, exchanging one pan for the other at the time that a measurement is required. Record rates at specific times during the test:
    - at failure call of the standard HOT plate (EG fluid)
    - at failure call of the 7.5 cm cold-soak box (EG fluid)
    - at failure call on the aircraft leading edge
    - at test end
- Record wind speed at the test stand before and after each run. Measure wind speed by moving along the rear of the stand, with the anemometer held over the rear edge of the test surfaces at a 2 m height above ground
- Record OAT and RH using the Vaisala meter with probe installed at a location free from influence of test equipment.

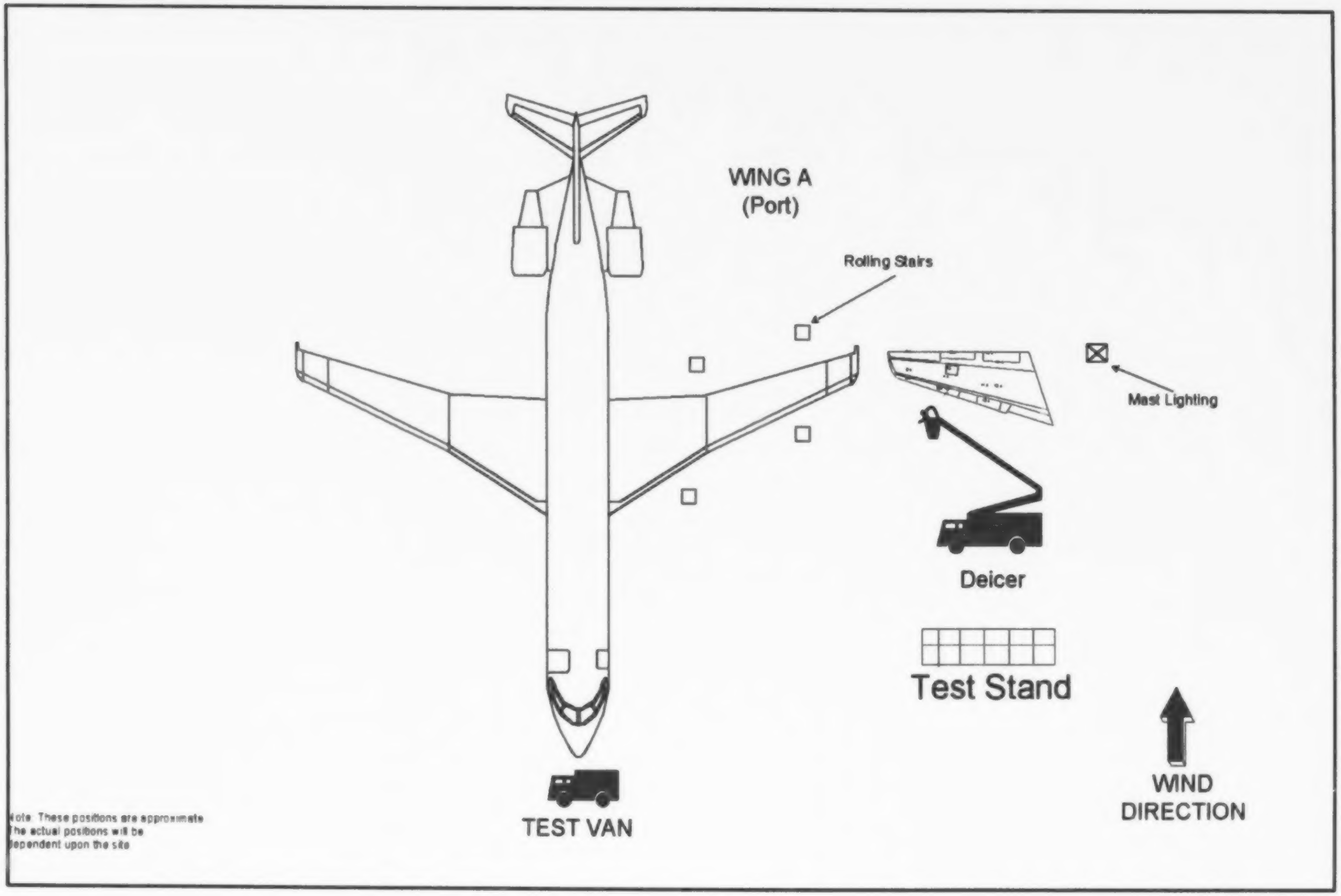
ATTACHMENT G-IV

SAFETY AWARENESS ISSUES
FIELD TRIALS FOR HOT WATER DEICING LIMITS

1) Review MSDS sheets for fluids at site.
2) Protective clothing is available.
3) Care should be taken when climbing rolling stairs due to slipperiness.
4) When moving rolling stairs, ensure they do not touch aircraft.
5) When taking fluid samples or measuring snow thickness on the aircraft, ensure minimum pressure is applied to the wing.
6) Entry into the aircraft cabin is not authorised.
7) When aircraft is being sprayed with fluid, testers and observers should be positioned away in the hold area.
8) First aid kit and fire extinguisher is available in mobile truck.
9) No smoking permitted on the ramp area.
10) Care to be taken when moving generators and fuel for the generators.
11) Electrical and instrumentation cabling will be present in the test area; do not trip over them. Do not roll stairs or other equipment over cables.
12) Gasoline containers are needed to power the generators - ensure you know where these are.
13) Ensure lights and rolling stairs are stabilised to not damage the wing.
14) Ensure all objects and equipment are removed from deicing pad at end of night.
15) Ensure all markings removed from wing.
16) Personnel with escort-required passes must always be accompanied by someone with a permanent pass.
17) Rolling stairs should always be positioned such that the stairs are into the wind. Small ladders should be laid down under windy conditions.
18) Tests involving personnel not trained and experienced in ramp operations must take particular care to ensure safety of personnel.

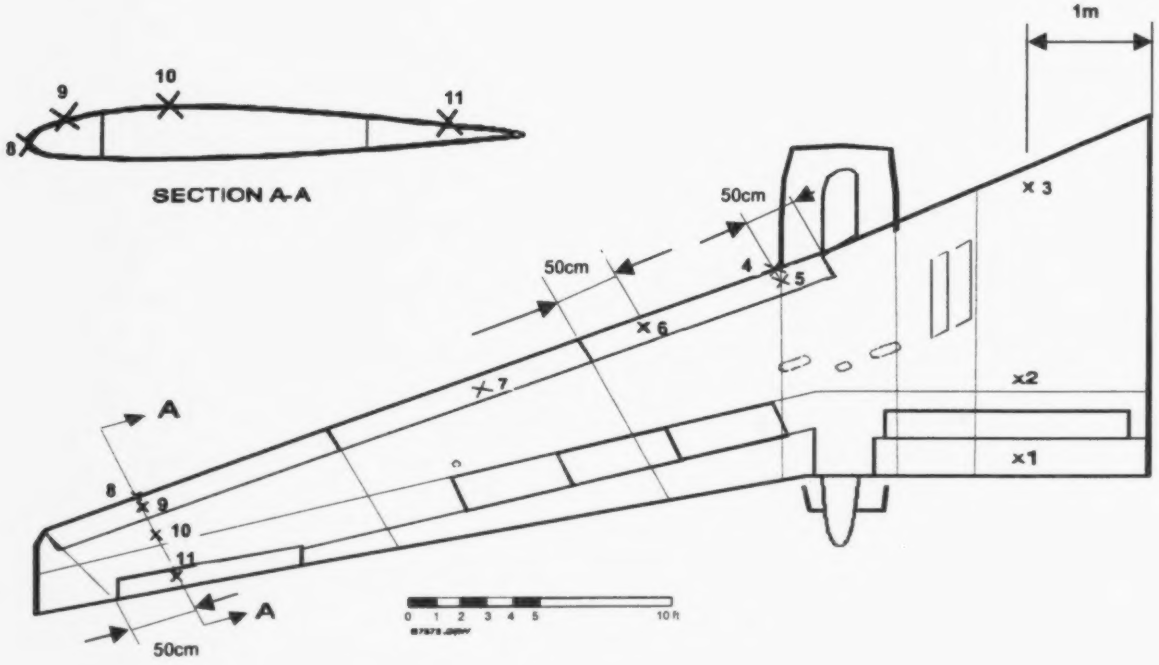
FIGURE G-1

EQUIPMENT POSITION


WING A
(Port)
Rolling Stairs
Mast Lighting
Deicer
Test Stand
TEST VAN
WIND
DIRECTION

Note: These positions are approximate
The actual positions will be
dependent upon the site

FIGURE G-2
Thermistor Probes Locations for B737 Wing
FIELD TRIALS FOR TYPE I TEST PROTOCOL

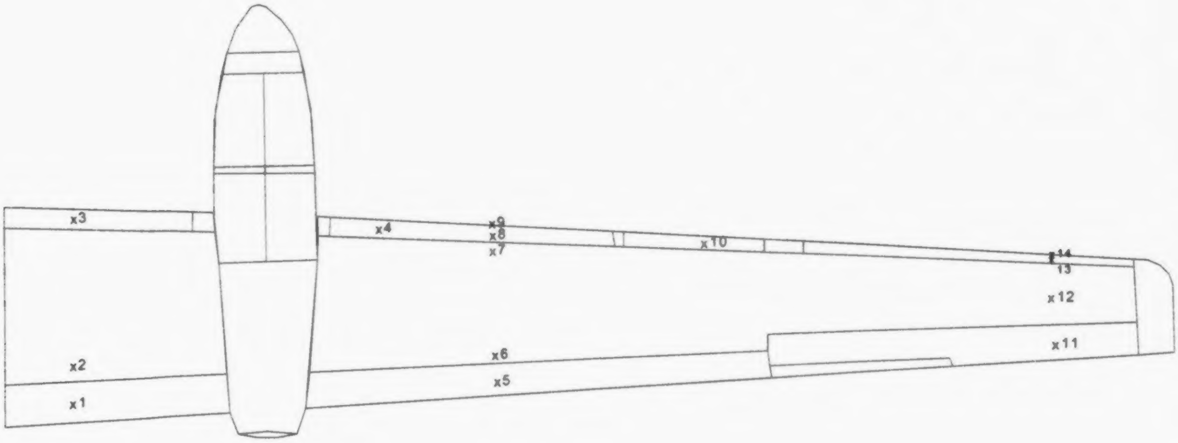

1m
9
10
11
8
SECTION A-A
50cm
x 3
4
5
50cm
x 6
x 7
x2
A
8
x 9
x 10
11
x1
A
50cm
0 1 2 3 4 5 10 ft

1. Mid-way on flap, 1 m from root
2. On main wing, max. distance reachable, 1 m from fuselage
3. 25cm back from LE nose, 1 m from fuselage
4. On nose of LE, 50 cm from inner end
5. Mid-way on surface, 50 cm from inner end
6. Mid-way on LE, 50 cm from outer end
7. Mid-way on LE, midpoint of LE section
8. On nose of LE, in chord with # 11
9. Mid way on LE, in chord with # 11
10. High point of wing in chord with # 11
11. Mid-way on aileron, 50 cm from outer end.

FIGURE G-2

Thermistor Probes Locations for Saab 340 Wing

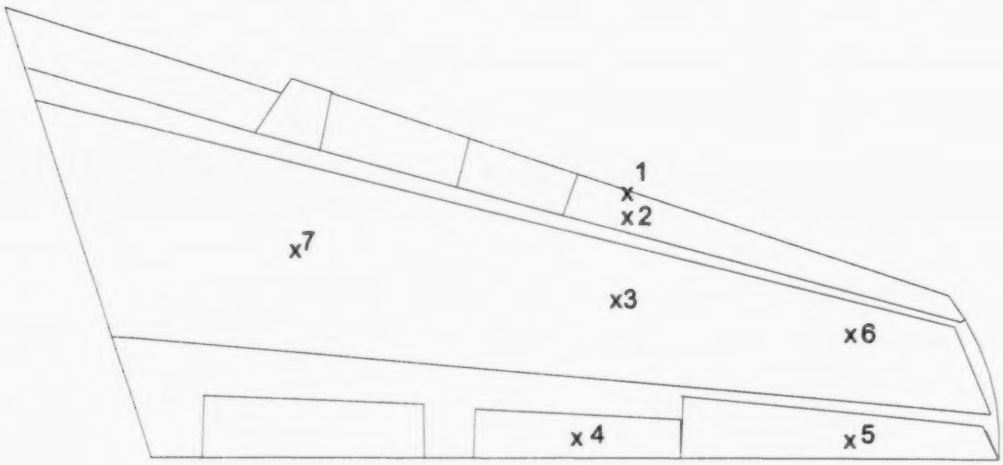
FIELD TRIALS FOR TYPE I TEST PROTOCOL



1. Midway on flap, 1/2 distance cabin to engine
2. 15 cm ahead of flap, 1/2 distance cabin to engine
3. Midway on LE, 1/2 distance cabin to engine
4. Midway on LE, 1/4 distance on LE from engine
5. Midway on flap, in line with 9
6. 15 cm ahead of flap, in line with 9
7. 15 cm behind LE, in line with 9
8. Midway on LE, in line with 9
9. On nose of LE, 1/4 distance from outer end of surface
10. Midway on LE, 1/2 way from surface end
11. Midway on aileron, 1/4 distance from outer end of surface
12. On high point of wing
13. Midway on LE, 1/4 way from outer end of surface
14. On nose of LE, 1/4 way from outer end of surface

FIGURE G-2
FIELD TRIALS FOR TYPE I TEST PROTOCOL

Thermistor Probes Mounting Locations on JetStar Test Wing



1. On nose of Leading Edge (LE)

2. On LE, 1/2 way from nose to rear joint

3,6,7 On main wing, at high point on chord

4,5 On flight control surfaces, 1/2 way from rear edge to front edge

FIGURE G-3

GENERAL FORM (ONCE PER SESSION)

(TO BE FILLED IN BY OVERALL COORDINATOR)

AIRPORT: YUL YYZ YOW

AIRCRAFT TYPE: F-100 B-737 RJ Saab 340

EXACT PAD LOCATION OF TEST: ______________________________

AIRLINE: ____________________

DATE: ____________________

FIN #: ____________________

APPROX. AIR TEMPERATURE: ________ °C

WING TANK FUEL LOAD: ____________________ **LB / KG**

STD TYPE I FLUID APPLICATION	***-10° C BUFFER TYPE I FLUID APPLICATION***
FLUID TEMP: ________ °C	**FLUID TEMP:** ________ °C
Truck #: ________	**Truck #:** ________
Type I Fluid Nozzle Type: ________	**Type I Fluid Nozzle Type:** ________

COMMENTS: ______________________________

MEASUREMENTS BY: ____________________

HAND WRITTEN BY: ____________________

FIGURE G-4

GENERAL FORM (EVERY TEST)

(TO BE FILLED IN BY BRIX SAMPLER)

DATE: ____________________

RUN #: ____________________

AIRCRAFT TYPE: F-100 B-737 RJ Saab 340

WING: PORT (A) STARBOARD (B)

DIRECTION OF AIRCRAFT: ________ DEGREES

DRAW DIRECTION OF WIND WRT WING:

1st FLUID APPLICATION

Snow Depth on Wing ____________________ cm

Actual Start Time: ____________________ am / pm

Actual End Time: ____________________ am / pm

Amount of Fluid Sprayed: ____________________ L / gal

Type of Fluid: ____________________

Temp. of Fluid at Nozzle ____________________ °C

Fluid Brix: ____________________

End of Test Time: ____________________ (hr:min:ss) am/pm

COMMENTS: ____________________

MEASUREMENTS BY: ____________________

HAND WRITTEN BY: ____________________

FIGURE G-5 – B737 Port

FLUID FAILURE FORM FOR LEADING EDGE AND WING OBSERVERS

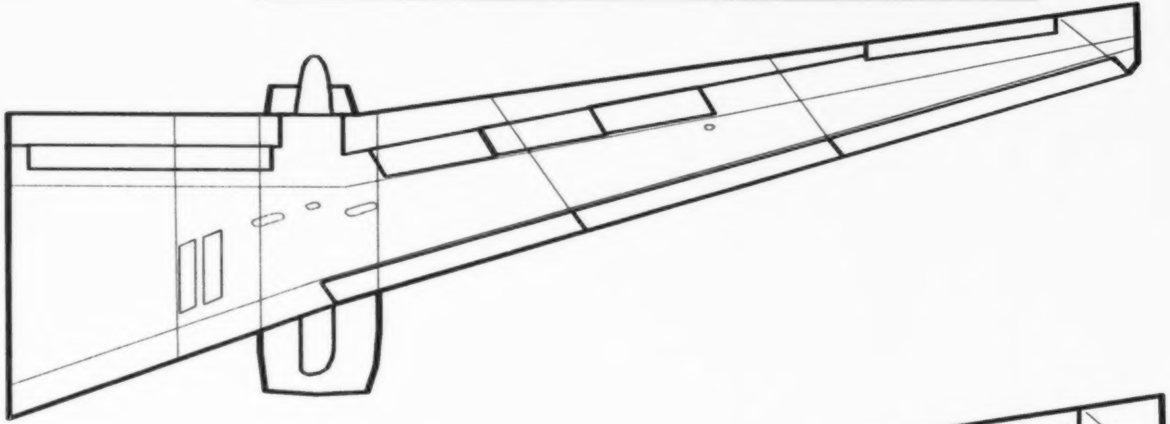
FIELD TRIALS FOR TYPE I TEST PROTOCOL

REMEMBER TO SYNCHRONIZE TIME VERSION 10 WINTER 2000/2001

DATE:	RUN NUMBER:	SPRAY TYPE:
FAILURES RECORDED BY: ______		

TIME: ______

DRAW Failure Contours at initial failure and every 2 to 5 minutes after.



TIME: ______

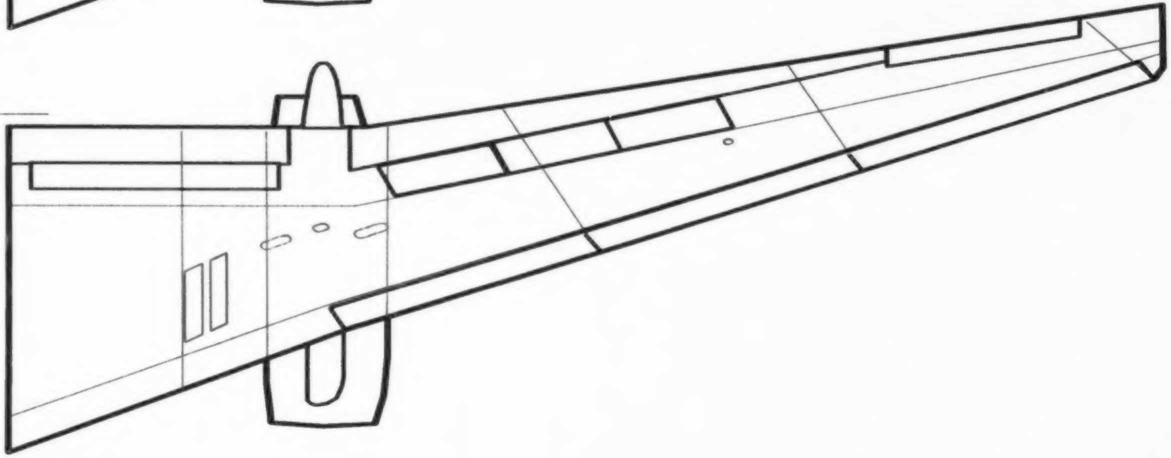


FIGURE G-5 – B737 Stbd.

FLUID FAILURE FORM FOR LEADING EDGE AND WING OBSERVERS
FIELD TRIALS FOR TYPE I TEST PROTOCOL

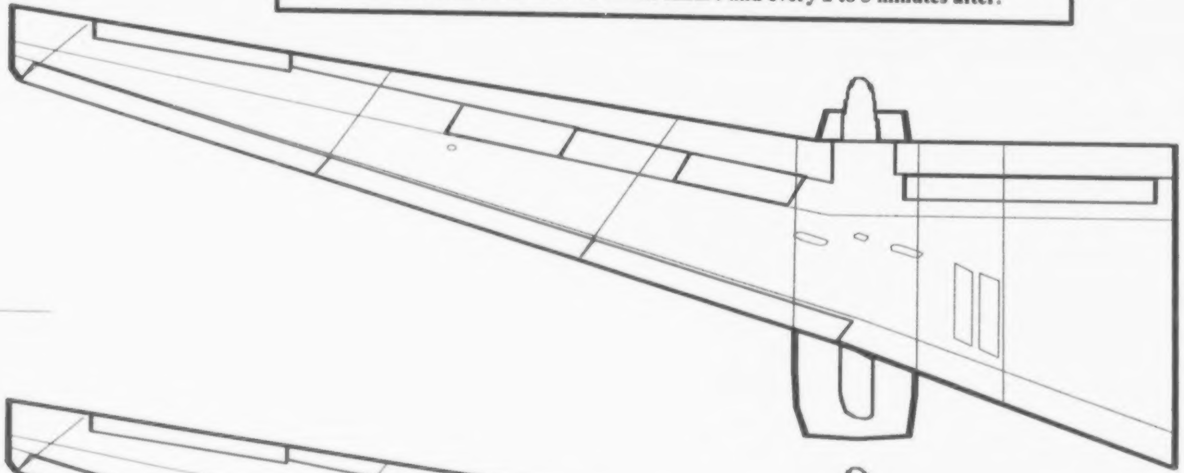
REMEMBER TO SYNCHRONIZE TIME

VERSION 10 WINTER 2000/2001

DATE:	RUN NUMBER:	SPRAY TYPE:
FAILURES RECORDED BY: ______		

TIME: ______

DRAW Failure Contours at initial failure and every 2 to 5 minutes after.



TIME: ______

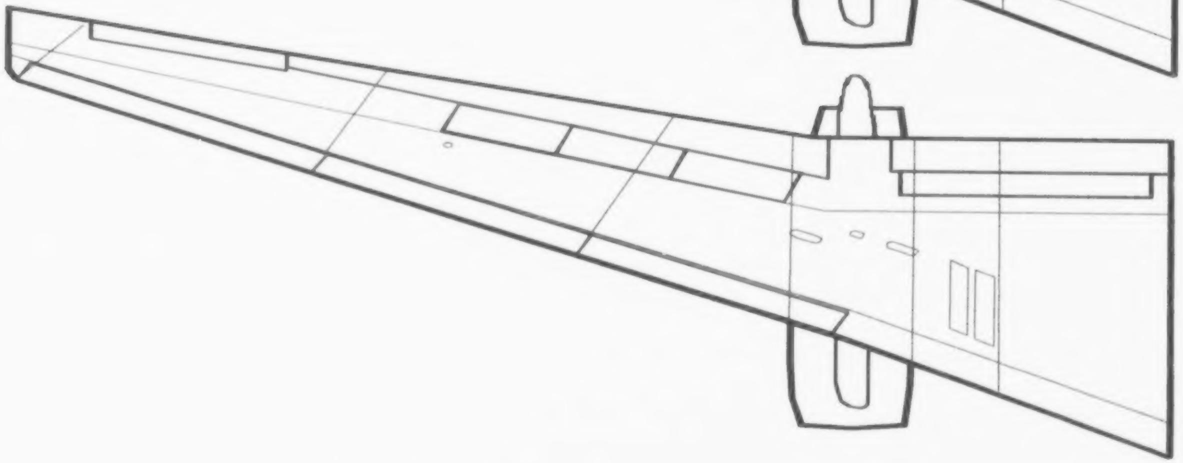


FIGURE G-5 – Saab 340 Port
FLUID FAILURE FORM FOR LEADING EDGE AND WING OBSERVERS
FIELD TRIALS FOR TYPE I TEST PROTOCOL

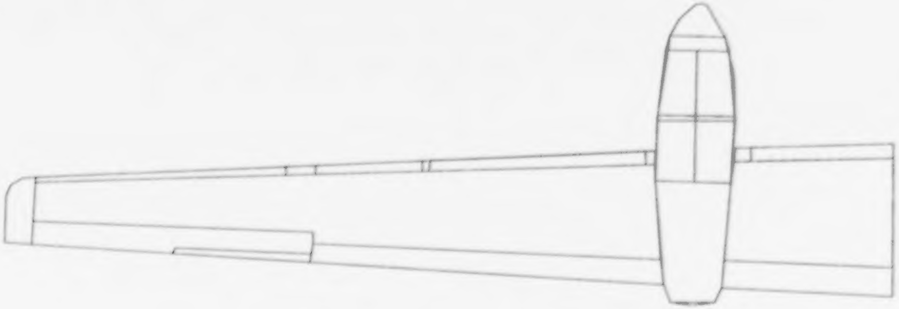
REMEMBER TO SYNCHRONIZE TIME

VERSION 10 WINTER 2000/2001

DATE:	RUN NUMBER:	SPRAY TYPE:
FAILURES RECORDED BY: ______________		

DRAW Failure Contours at initial failure and every 2 to 5 minutes after.

TIME: ______________



TIME: ______________

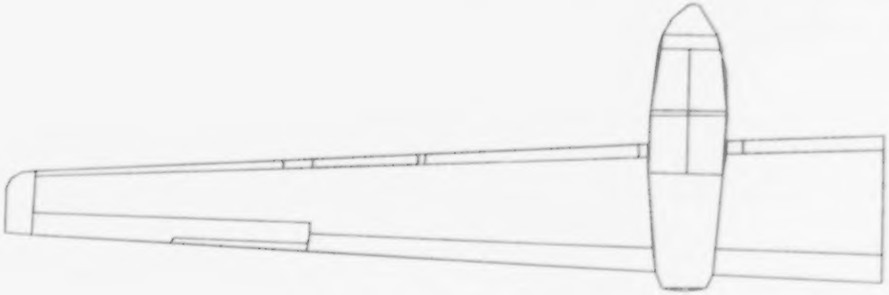


FIGURE G-5 – Saab 340 Stbd.
FLUID FAILURE FORM FOR LEADING EDGE AND WING OBSERVERS
FIELD TRIALS FOR TYPE I TEST PROTOCOL

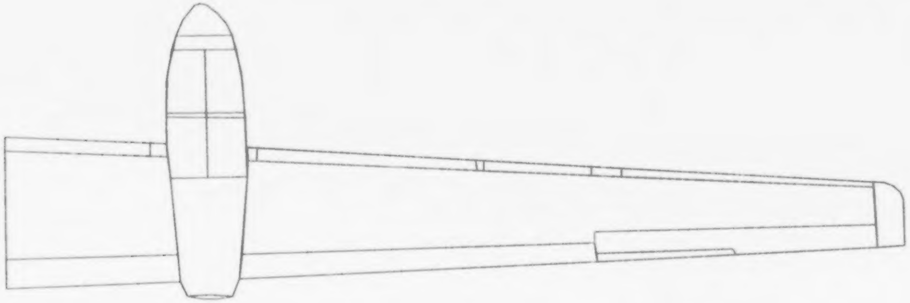
REMEMBER TO SYNCHRONIZE TIME

VERSION 10 WINTER 2000/2001

DATE:	RUN NUMBER:	SPRAY TYPE:
FAILURES RECORDED BY: ______________________		

DRAW Failure Contours at initial failure and every 2 to 5 minutes after.

TIME: ______________



TIME: ______________

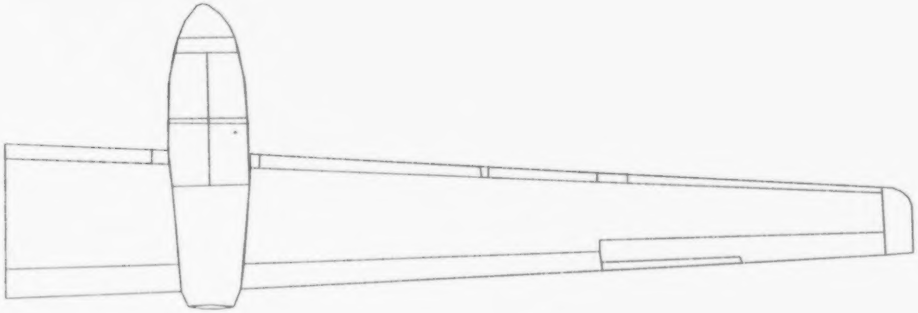


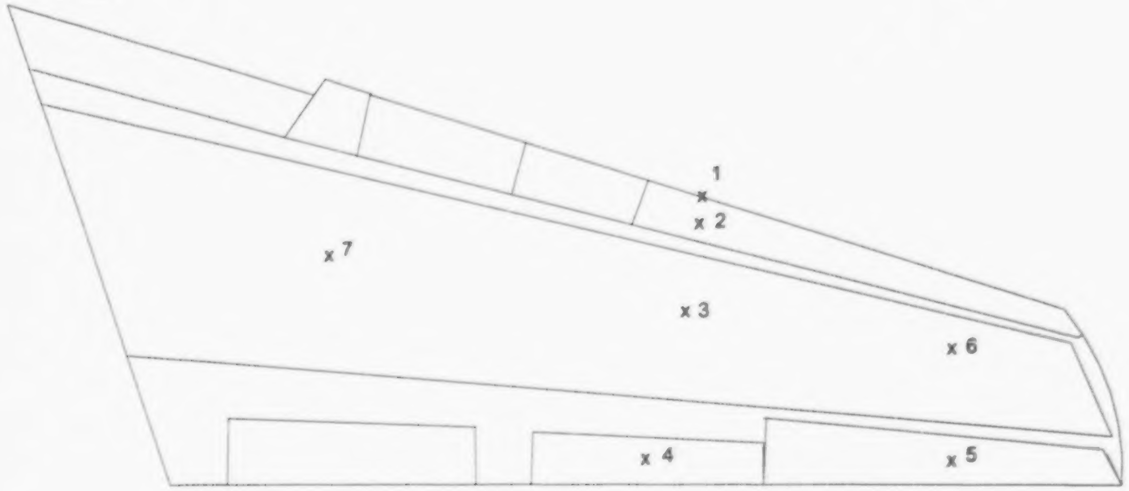
FIGURE G-5 – JETSTAR TEST WING
FLUID FAILURE FORM FOR LEADING EDGE AND WING OBSERVERS
FIELD TRIALS FOR TYPE I TEST PROTOCOL

REMEMBER TO SYNCHRONIZE TIME VERSION 10 WINTER 2001/2002

DATE:	RUN NUMBER:	SPRAY TYPE:
FAILURES RECORDED BY:______________________________		

DRAW Failure Contours at initial failure and at time of each plate failure

TIME: ____________



TIME: ____________

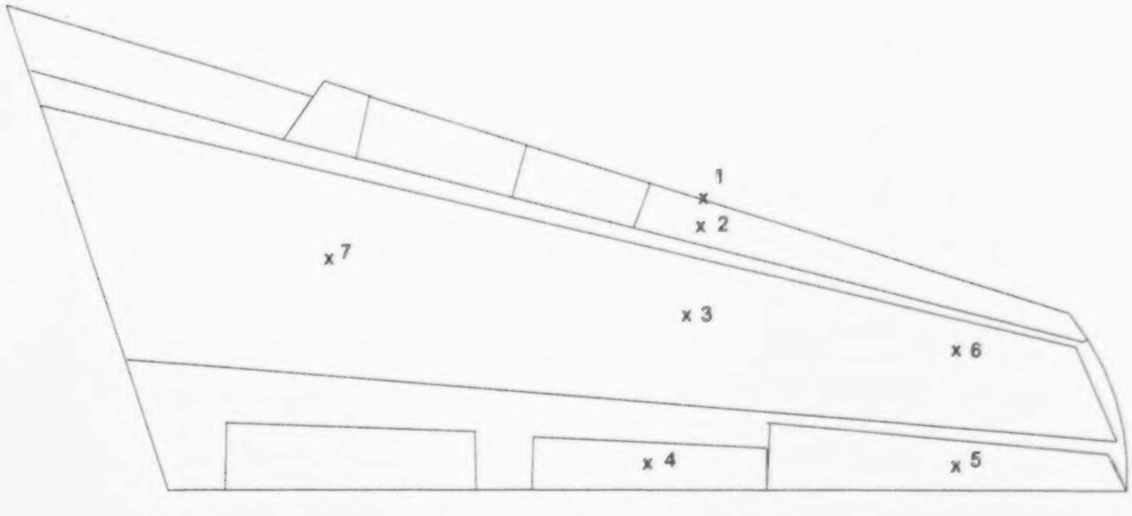


FIGURE G-6 – B737
BRIX FORM FOR B737 WING TRIALS
TYPE I TEST PROTOCOL

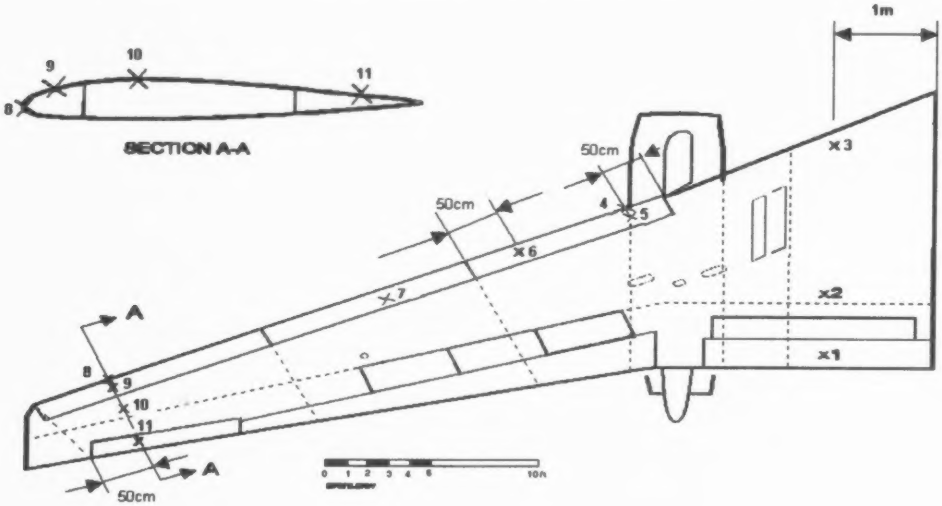
DATE: ____________________

RUN #: __________

Final Drip Line Brix: __________

Snow Depth on Wing: __________

Wing Location 4		Wing Location 5		Wing Location 11		Cold-soak BOX EG		Std. HOT Plate EG	
Time	Brix	Time	Brix	Time	Brix	Time	Brix	Time	Brix


9
10
11
8
SECTION A-A
1m
50cm
50cm
4
5
6
7
x3
x2
x1
A
8
9
10
11
A
50cm
0 1 2 3 4 5 10ft

COMMENTS: ______________________________

____

____

BRIX MEASUREMENTS BY: ____________________

HANDWRITTEN BY: ____________________

FIGURE G-6 – Saab 340
BRIX FORM FOR Saab 340 WING TRIALS
TYPE I TEST PROTOCOL

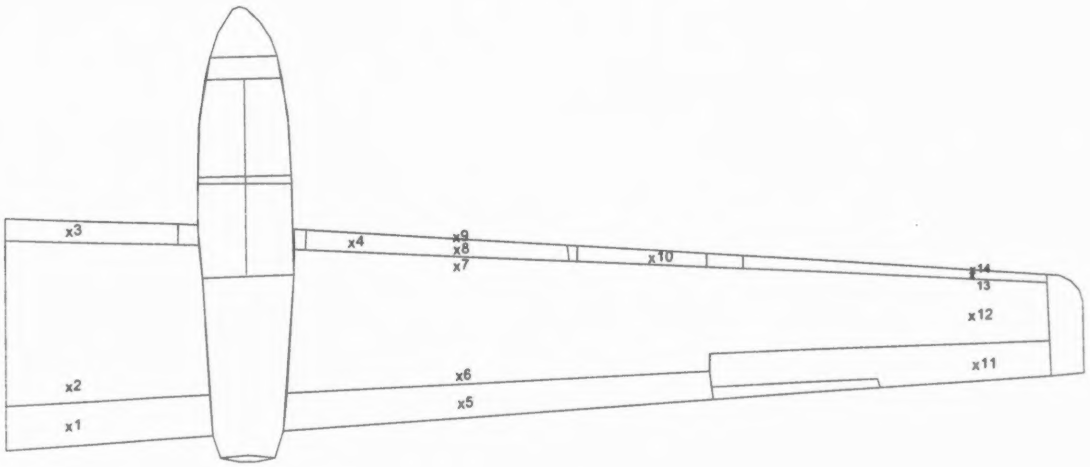
DATE: ____________________

Final Drip Line Brix: __________

RUN #: __________

Snow Depth on Wing: __________

Wing Location 8		Wing Location 9		Wing Location 11		Cold-soak BOX EG		Std. HOT Plate EG	
Time	Brix	Time	Brix	Time	Brix	Time	Brix	Time	Brix



COMMENTS: ______________________________

BRIX MEASUREMENTS BY: ____________________

HANDWRITTEN BY: ____________________

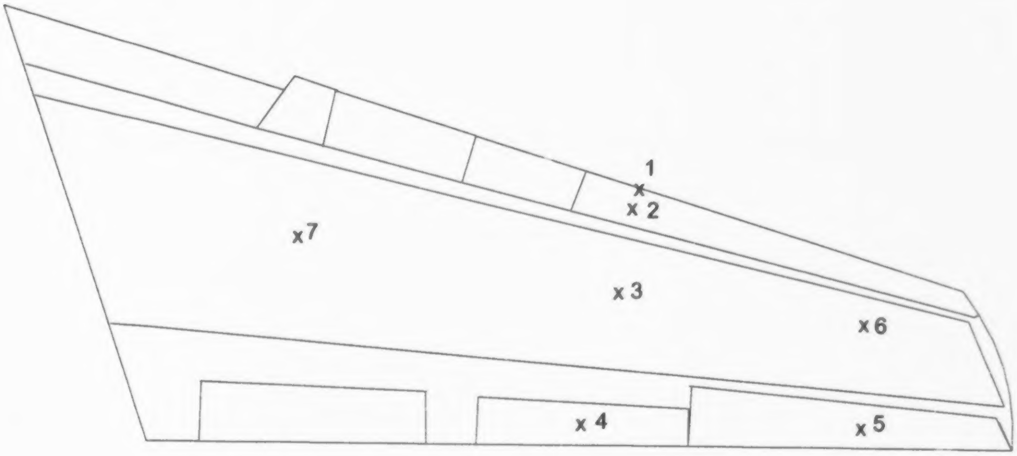
FIGURE G-6 – JetStar

BRIX FORM FOR JETSTAR WING TRIALS
TYPE I TEST PROTOCOL

DATE: ____________________ RUN #: __________

Final Drip Line Brix: __________ Snow Depth on Wing: __________

Wing Location 4		Wing Location 5		Std. HOT Plate		Std. BOX		Location	
Time	Brix	Time	Brix	Time	Brix	Time	Brix	Time	Brix



COMMENTS: ______________________________

BRIX MEASUREMENTS BY: ____________________

HANDWRITTEN BY: ____________________

FIGURE G-7

END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 6.0 Winter 2000/2001

LOCATION: **DATE:** **RUN # :** **STAND # :**

CIRCLE SENSOR PLATE: u v w x y z

SENSOR NUMBER: __ __ __ __ __ __

DIRECTION OF STAND: ____ °

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

____

____

	PRINT	SIGN
FAILURES CALLED BY :		
HAND WRITTTEN BY :		
TEST SITE LEADER :		

***TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (hr:min)**

Time of Fluid Application: ____ hr:min:ss ____ hr:min:ss ____ hr:min:ss

	Plate U			Plate V			Plate W		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / TEMPERATURE AT START	/			/			/		

Time of Fluid Application: ____ hr:min:ss ____ hr:min:ss ____ hr:min:ss

	Plate X			Plate Y			Plate Z		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / TEMPERATURE AT START	/			/			/		

FIGURE G-8 – B737 Port

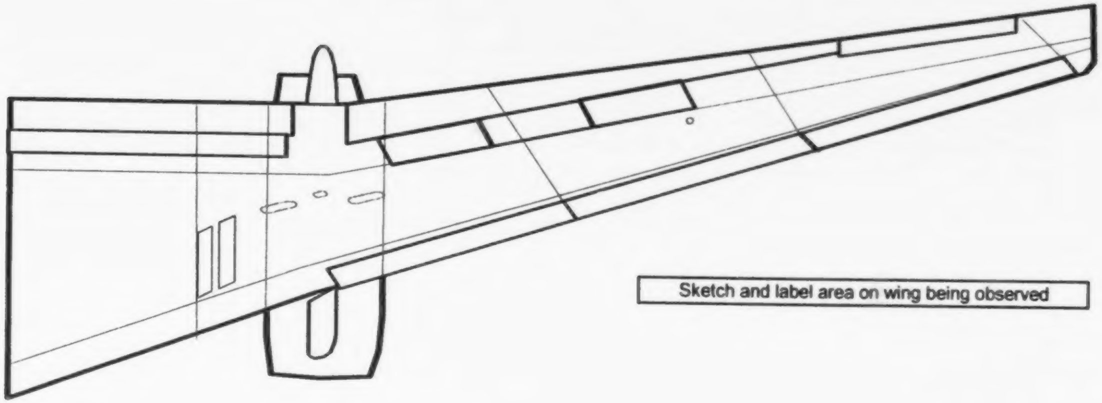
FAILED FLUID ROUGHNESS FORM
FIELD TRIALS FOR TYPE I TEST PROTOCOL

REMEMBER TO SYNCHRONIZE TIME

WINTER 2001/2002

DATE: ______________ RUN NUMBER: ______________

RECORDED BY: ______________ SIGNATURE: ______________ SPRAY TYPE: ______________



Sketch and label area on wing being observed

OBSERVED AREA	TIME	ICE HEIGHT		ADHERENCE Y / N
		MAX.	MIN.	

FIGURE G-8 – Saab 340 Port

FAILED FLUID ROUGHNESS FORM
FIELD TRIALS FOR TYPE I TEST PROTOCOL

REMEMBER TO SYNCHRONIZE TIME

WINTER 2001/2002

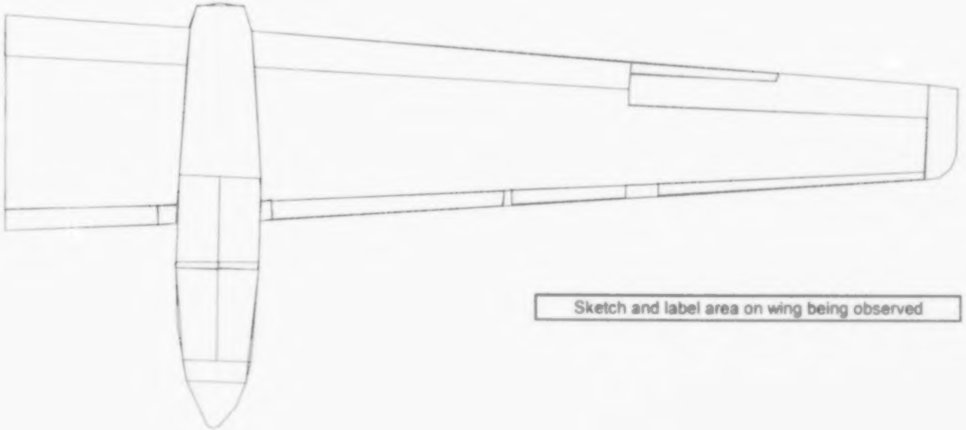
DATE: ______________

RUN NUMBER: ______________

RECORDED BY: ______________

SIGNATURE: ______________

SPRAY TYPE: ______________



Sketch and label area on wing being observed

OBSERVED AREA	TIME	ICE HEIGHT		ADHERENCE Y / N
		MAX.	MIN.	

FIGURE G-8 – JetStar Test Wing

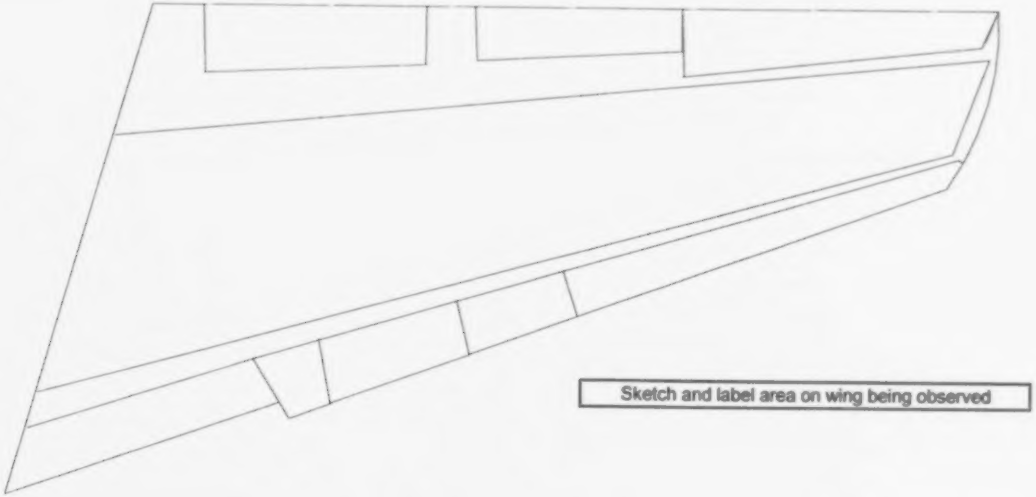
FAILED FLUID ROUGHNESS FORM
FIELD TRIALS FOR TYPE I TEST PROTOCOL

REMEMBER TO SYNCHRONIZE TIME

WINTER 2001/2002

DATE: ______________ RUN NUMBER: ______________

RECORDED BY: ______________ SIGNATURE: ______________ SPRAY TYPE: ______________



Sketch and label area on wing being observed

OBSERVED AREA	TIME	ICE HEIGHT		ADHERENCE Y / N
		MAX.	MIN.	

FIGURE G-9
METEO / PLATE PAN DATA FORM - TYPE I PROTOCOL

TIME WITH AES - USE REAL TIME

VERSION 1.0 Winter 2000/2001

DATE: **RUN # :** **STAND # :**

PLATE PAN WEIGHT MEASUREMENTS *

BUFFER TIME (Seconds)	t TIME AFTER (hh:mm:ss)	BUFFER TIME (Seconds)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE (Δw* 4.7/Δ t) (g/dm²/h)

ALS (STAGGERED)

METEO OBSERVATIONS **

TIME (hr:min)	TYPE ZR, ZL,S, SG IP, IC, BS, SP	SNOW CLASSIF. (See Fig. 3)	OAT (°C)	WIND SPEED at 2 m (Km/h)

**observations at beginning, end, and every 10 min. intervals. Additional observations when there are significant changes

COMMENTS : ____________________

____

____

____

	PRINT	SIGN
WRITTEN & PERFORMED BY :		
PHOTO BY :		
TEST SITE LEADER :		

RESULTS

PLATE/BOX SURFACE TEMPERATURE PROFILES AND JETSTAR WING TEMPERATURE PROFILES

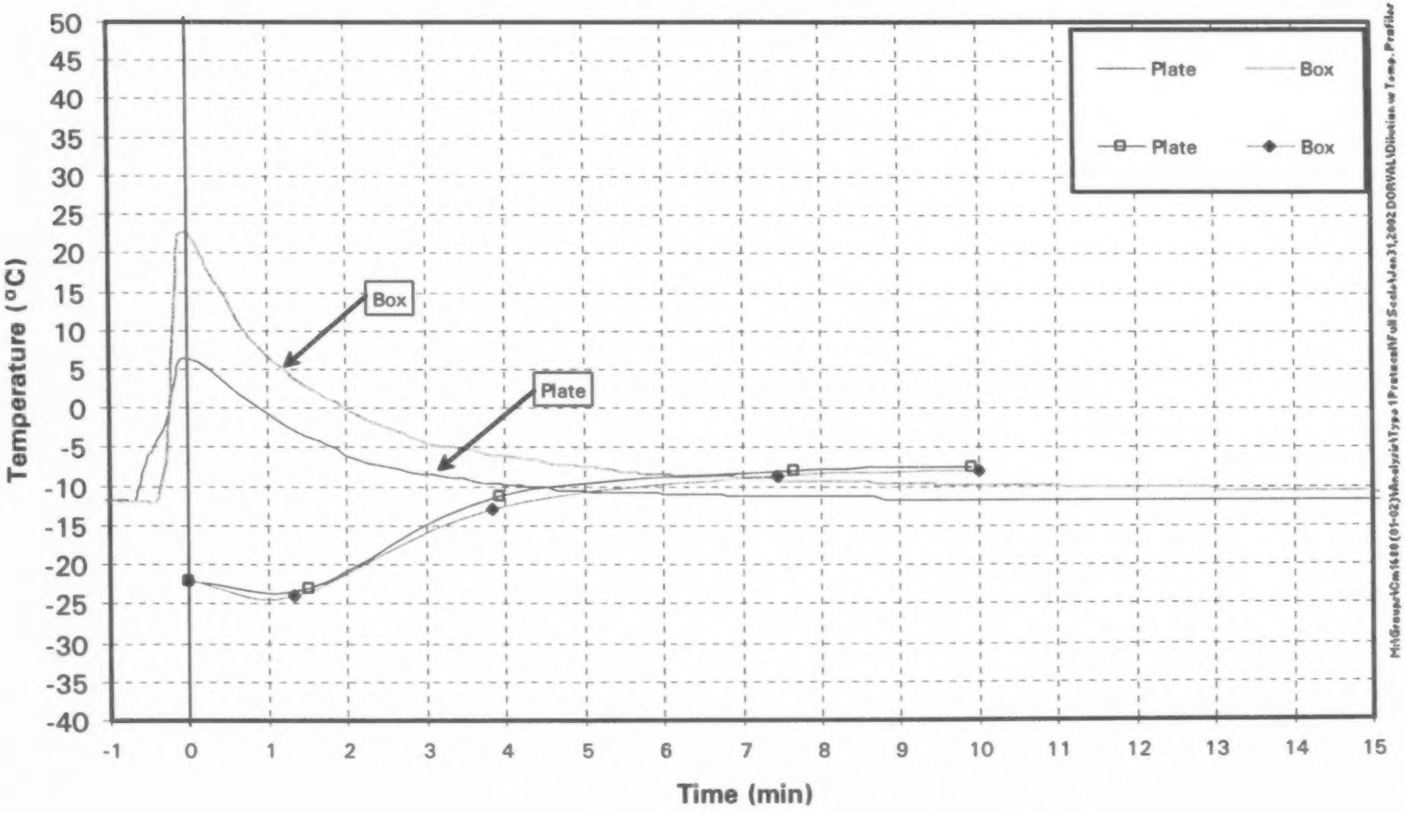
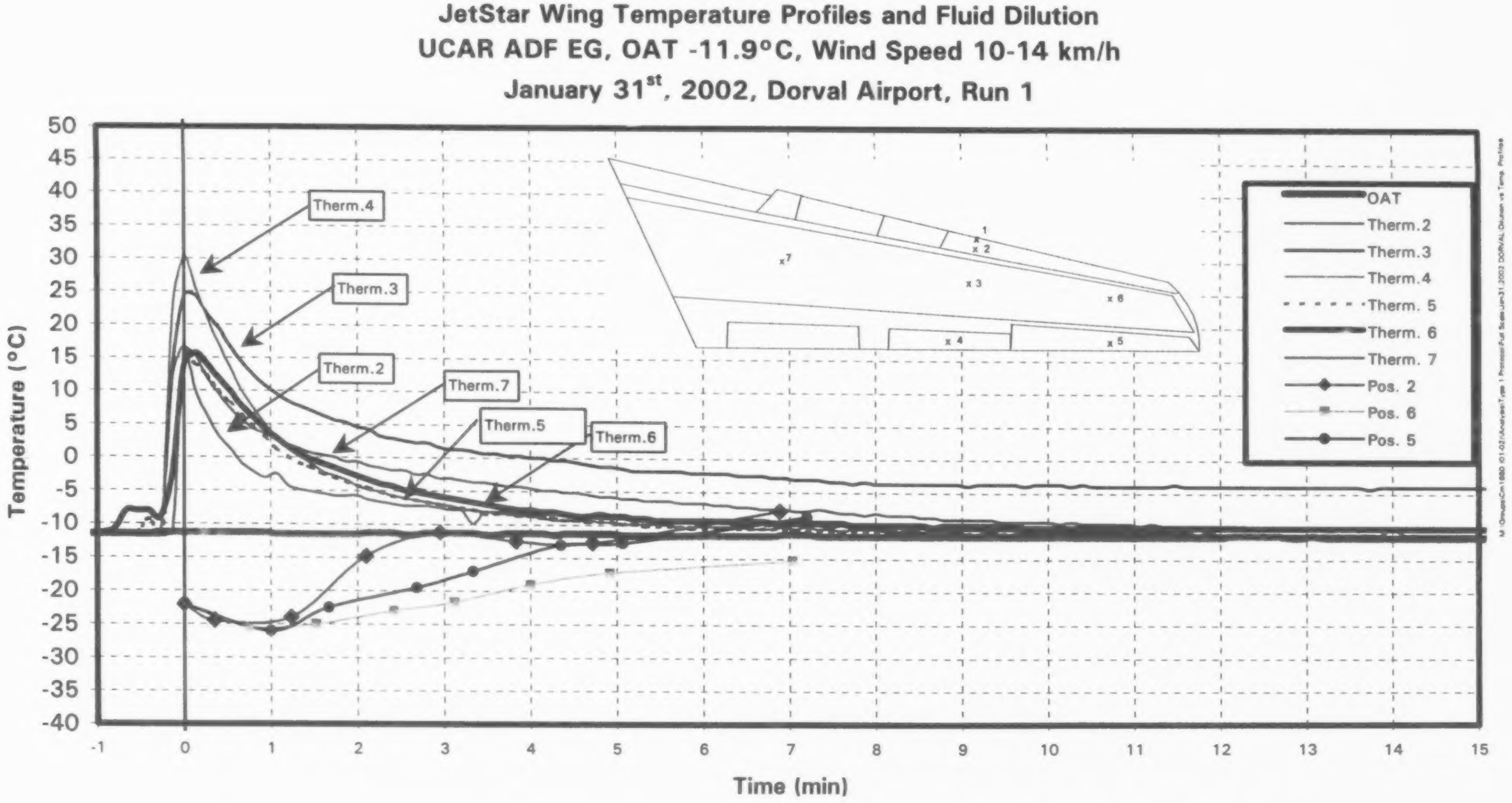


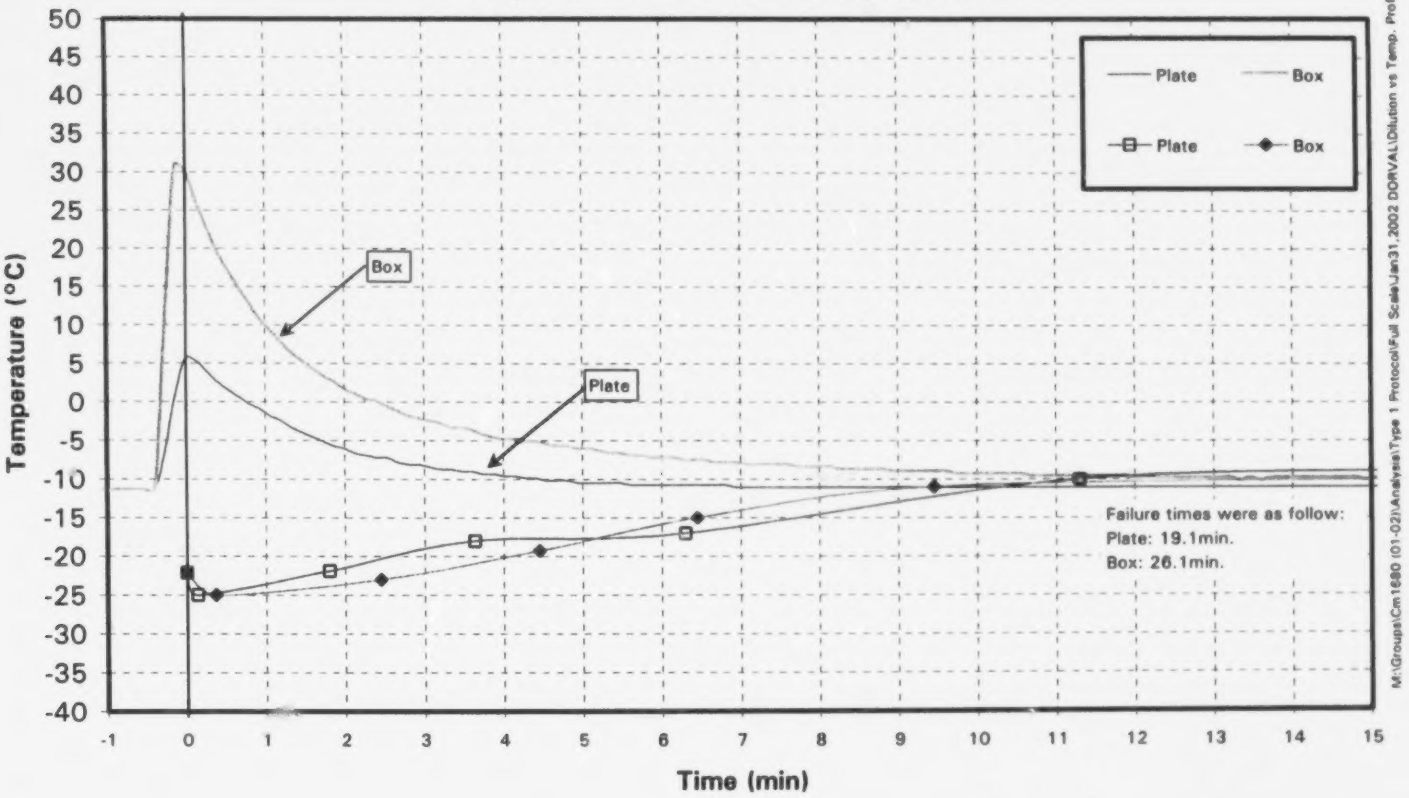
Plate / Box Surface Temperature Profiles and Fluid Dilution
UCAR ADF EG, OAT -11.9°C, Wind Speed 10 -14 km/h, Rate ~11 g/dm^2/h
January 31st, 2002, Dorval Airport, Run 1

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\Full Scale\Jan31,2002 DORVAL\Dilution w Temp. Profiles

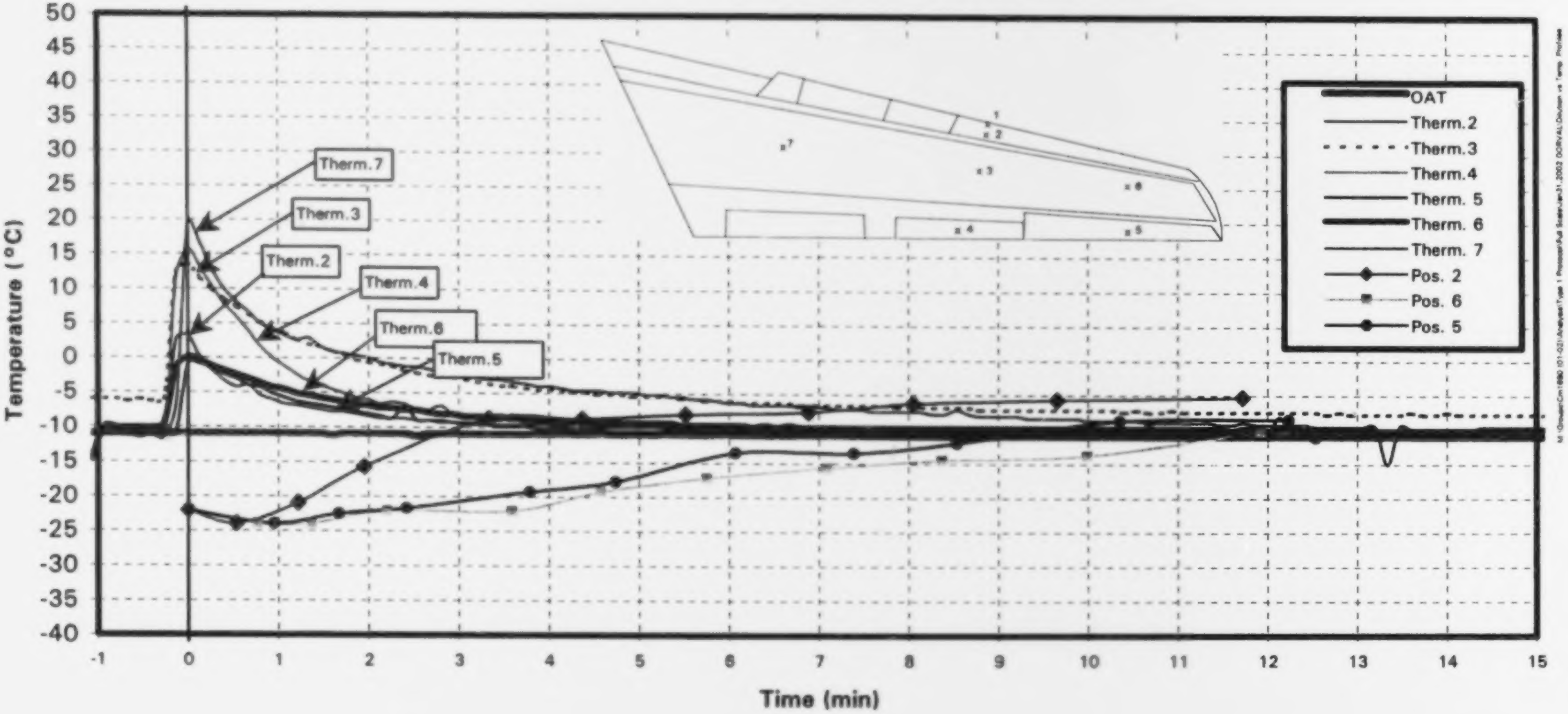


JetStar Wing Temperature Profiles and Fluid Dilution
UCAR ADF EG, OAT -11.9°C, Wind Speed 10-14 km/h
January 31st, 2002, Dorval Airport, Run 1

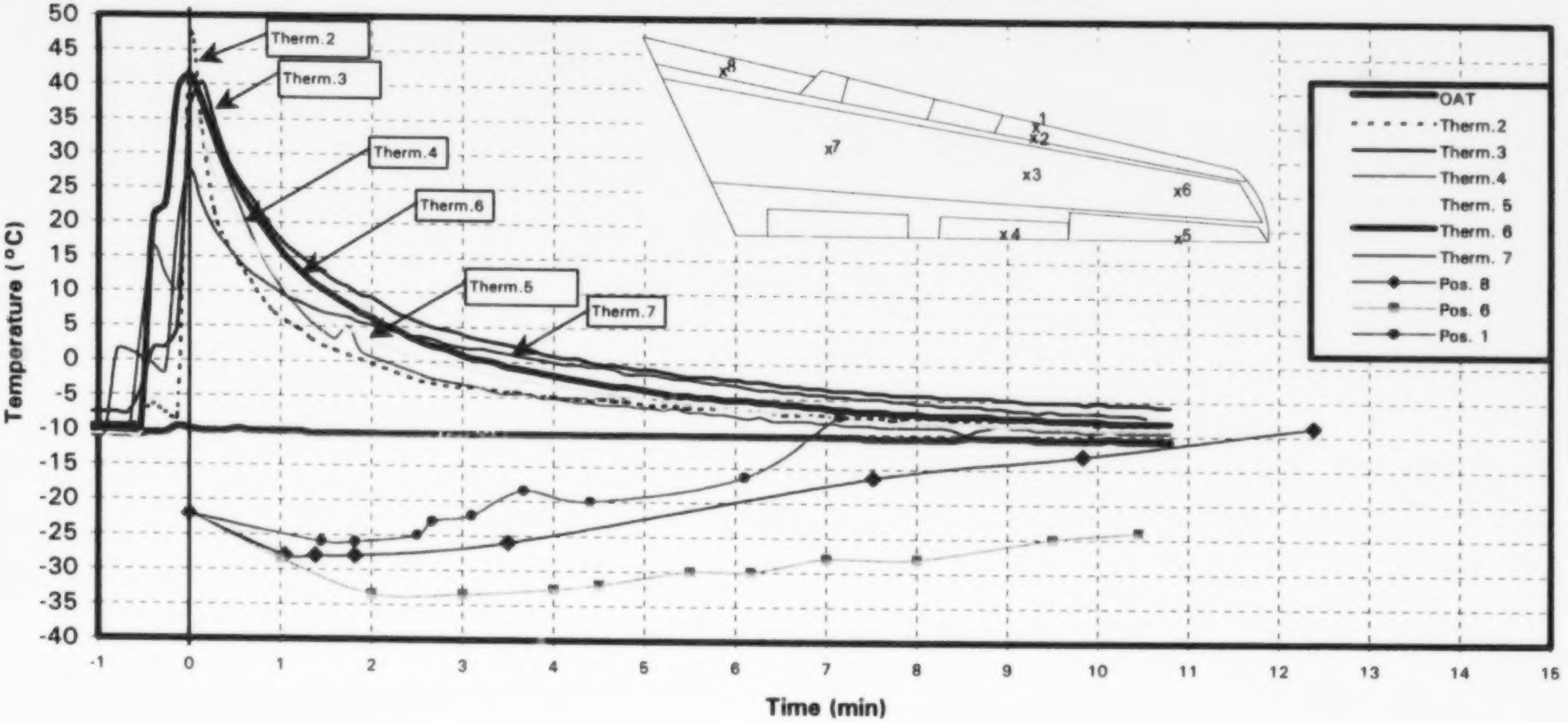
Plate / Box Surface Temperature Profiles and Fluid Dilution
UCAR ADF EG, OAT -11°C, Wind Speed 25 km/h, Rate ~4.4 $g/dm^2/h$
January 31st, 2002, Dorval Airport, Run 2



JetStar Wing Temperature Profiles and Fluid Dilution
UCAR ADF EG, OAT -11°C, Wind Speed 25 km/h
January 31st, 2002, Dorval Airport, Run 2



JetStar Wing Temperature Profiles and Fluid Dilution
UCAR ADF EG, OAT ~ -11°C
January 31st, 2002, Dorval Airport, Run 3



H

APPENDIX H

EXPERIMENTAL PROGRAM
FOR THE DETERMINATION OF OUTDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL

CM1680.001

EXPERIMENTAL PROGRAM
DETERMINATION OF OUTDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL

Winter 2001/2002

Prepared for

Transportation Development Centre
Transport Canada

for Prepared by: Nicoara Moc

Reviewed by: John D'Avirro

January 7, 2002
Version 2.0

APS AVIATION INC.

EXPERIMENTAL PROGRAM
DETERMINATION OF OUTDOOR ENDURANCE TIMES OF TYPE I FLUIDS USING THE NEW TEST PROTOCOL
Winter 2001/2002

1. BACKGROUND

Due to problems found by the industry, a new protocol that would more closely simulate the nature of anti-icing operations under natural conditions, is in development.

It was concluded that the current Type I test procedure with flat plates used in 2000-2001 winter, when conducted outdoors in natural wind did not provide a good simulation of actual deicing operations and did not produce a surface temperature decay rate that matched real wings. Shortened fluid endurance times would result.

Following examination of several test surfaces and various procedures for fluid application, it was concluded that the 7.5 cm cold-soak box, empty, when treated with 0.5 L of fluid at 60°C, produced a reasonable representation of the temperature decay rate demonstrated by wings in natural outdoor conditions. A full account of these tests can be found in TP13827E Report, *SAE Type I Fluid Endurance Time Test Protocol*, October 2001.

2. OBJECTIVES

The objective of this procedure is to measure Endurance Time (ET) of Type I fluids that takes account of contribution of heat and reflects real field operations.

To achieve this objective, a series of tests will be conducted using SAE Type I fluid, on the regular ET plate for baseline purposes and the new cold-soak box surfaces.

3. PROCEDURE/TEST REQUIREMENTS

The 7.5 cm cold-soak box, empty, and the regular ET plate are the recommended test surfaces for the outdoor tests.

For the ET plate baseline tests, the recommended fluid temperature is 20°C and the quantity is 1.0 L, as per standard procedures for ET tests. The Type I fluid will be diluted to a freeze point 10°C below ambient temperature, unless otherwise noted.

For the 7.5 cm cold-soak box, the recommended fluid temperatures is 60°C with an acceptance range of +2°C and -0°C. The recommended quantity is 0.5 L, and the fluid will be applied on the surface through a spreader. The fluid used will be diluted to a freeze point 10°C below ambient temperature and also (lower priority) to a standard mix (the standard mix used in North America, which is close to a concentration of 50/50).

For this experiment two ET plates and three cold-soak boxes will be placed on the stand at the same time. At least 20 tests will be conducted for each surface and fluid type.

The tests will be conducted using propylene-based, and repeated with ethylene-based Type I fluid.

In order to have a more accurate representation of the holdover time obtained in real field deicing operations, the trials need to be performed at different temperatures and rates, over several snowstorms.

The steps to be followed in conducting these tests are:

1. Synchronize computer and test clocks to atomic clock.
2. Follow standard procedures for ET tests except as described below.
3. Prepare surfaces on the stand in accordance with Table H-1.
4. Prepare fluid (Section 4.2) for testing. The types of surfaces, positions and fluid amounts to be tested are shown in Table H-1.

Table H-1
Test Stand Positions

STAND POS.	SURFACE TYPE	FLUID		Fluid Conc.	Fluid Type*
		AMOUNT (L)	TEMP (°C)		
1	RATE PAN				
2	Standard plate for ET test	1	20	10° Buffer	E
3	Standard plate for ET test	1	20	10° Buffer	P
4	7.5 cm box (empty)	0.5	60	10° Buffer	E
5	7.5 cm box (empty)	0.5	60	10° Buffer	P
6	7.5 cm box (empty)	0.5	60	Std. mix	E or P

* E – Ethylene (Dow/UCAR EG ADF)
P – Propylene (Dow/UCAR PG ADF)

5. Pour required amount of heated fluid into thermos containers for application.

6. First, apply the fluid to the three cold-soak boxes on the stand. Pour the fluid on the test surfaces in quick succession to avoid cooling of the spreader between pours. The spreader is modified (taped) to allow fluid to come out through only ½ the number of holes (12 holes). Just before pouring, the box surfaces should be cleaned according to the following procedure:

   - Clean the surface of all contamination with scraper and squeegee.
   - Wet a clean wiper cloth with fluid at ambient temperature and wipe the plate over its entire surface. (This is intended to ensure that the surface is wetted as well as clean, to assist in complete coverage with the applied fluid.).

7. Standing behind the stand, place a shield device to deflect the air and pour the test fluid from the thermos into the spreader. Remove the shield when the spreader has emptied.

8. Then, apply fluid to the standard ET surfaces according to the standard method. (Clean the plate with scraper and squeegee, pour about 1/3 of the fluid over the plate, squeegee dry, and then pour the remainder of the fluid along the top edge.)

9. Determine failure times on test surfaces, and record using standard ET data forms (Attachment H-1). Right after failure record also the fluid brix and the plate temperature.

10. Measure precipitation rates and record using the Meteo/Plate data form (Attachment H-2).

11. Record rates. As per Table H-1, position 1 on the stand will be used for measuring snow deposition rates. Use two rate pans in a 5 minute routine. At the time that a measurement is required, the pan that needs to be weighed will be replaced on the stand by the other pan. This cycle will continue until the last surface failed. While pouring the fluid on the test surfaces care should be taken that no contamination falls in the rate pans (use a shield device if necessary).

12. Record wind speed at the test stand before and after each run. Measure wind speed by moving along the rear of the stand, with the anemometer held over the rear edge of the test surfaces at a 2 m height above ground.

4. EQUIPMENT AND FLUIDS

4.1 Equipment

Use the same equipment that is used for ET trials.

Candidate test surfaces used for these trials will be:

- Two standard ET plate
- Three 7.5 cm cold-soak boxes (empty)

A wind shield and fluid spreader device will be used for applying fluids.

A handheld anemometer is needed to measure wind speed at the test stand.

4.2 Fluids

Tests shall be conducted with ethylene-based and propylene-based Type I fluids. Fluids are to be mixed to a freeze point 10°C below OAT and also to the standard mix.

Fluids to be applied to the cold soak box test surfaces will be heated to 60°C. Fluids for standard ET tests will be heated to 20°C.

5. PERSONNEL

Three technicians:

- First calls failures, prepares fluid samples
- Second helps prepare and pour fluids
- Third measures rates and wind.

6. DATA FORMS

Use end condition forms from standard ET procedure (Attachment H-1).
For rate measurements, see Attachment H-2.

ATTACHMENT H-1
END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH ATOMIC CLOCK - USE REAL TIME

VERSION 2.0 Winter 2001/2002

LOCATION: DORVAL TEST SITE **DATE:**

RUN #: **STAND # :**

LOCATION OF SURFACES ON THE STAND

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

***TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (hr:min)**

Time of Fluid Application: ______ hr:min:ss ______ hr:min:ss ______ hr:min:ss

	Plate / BOX ____			Plate / BOX ____			Plate / BOX ____		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / FLUID TEMPERATURE AT START	/			/			/		
BRIX / PLATE TEMPERATURE AT FAILURE	/			/			/		

Time of Fluid Application: ______ hr:min:ss ______ hr:min:ss ______ hr:min:ss

	Plate / BOX ____			Plate / BOX ____			Plate / BOX ____		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / FLUID TEMPERATURE AT START	/			/			/		
BRIX / PLATE TEMPERATURE AT FAILURE	/			/			/		

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

____

FAILURES CALLED BY : ____________ (PRINT) ____________ (SIGN)

ATTACHMENT H-2
METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH ATOMIC CLOCK - USE REAL TIME

VERSION 1.0 Winter 2001/2002

LOCATION: DORVAL TEST SITE **DATE:** **RUN # :** **STAND # :**

PLATE PAN WEIGHT MEASUREMENTS

PAN #	t TIME BEFORE (hh:mm:ss)	BUFFER TIME (Seconds)	t TIME AFTER (hh:mm:ss)	BUFFER TIME (Seconds)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE (Δw*4.7/Δ t) (g/dm²/h)

METEO OBSERVATIONS *

TIME (hr:min)	TYPE ZR, ZL, S, SG IP, IC, BS, SP	SNOW CLASSIF. (See Fig. 3)	WIND SPEED at 2 m (Km/h)

*observations at beginning, end, and every 5 min intervals. Additional observations when there are significant changes

COMMENTS : ____

____

____

____

	PRINT	SIGN
WRITTEN & PERFORMED BY :		
PHOTO BY :		

I

APPENDIX I

EXPERIMENTAL PROGRAM FOR THE CONDUCT OF TYPE I ENDURANCE TIME TESTS ON COLD-SOAK BOXES AT QUEBEC CITY AIRPORT (YQB)

CM1680.001

NB: ***This document was prepared in anticipation of its use at YQB. On January 24, 2002, APS was informed that FAA/TC did not want to procede due to the difficulty in determining the failure calls and procedures.***

EXPERIMENTAL PROGRAM FOR THE CONDUCT OF TYPE I ENDURANCE TIME TESTS ON COLD-SOAK BOXES AT QUEBEC CITY AIRPORT (YQB)

Winter 2001-02

Prepared for

Transportation Development Centre
Transport Canada

Federal Aviation Administration

American Eagle Airlines

Prepared by: Michael Chaput

Reviewed by: John D'Avirro

APS AVIATION INC. APS

January 23, 2002
Version 1.0

EXPERIMENTAL PROGRAM FOR THE CONDUCT OF TYPE I ENDURANCE TIME TESTS ON COLD-SOAK BOXES AT QUEBEC CITY AIRPORT (YQB)

Winter 2001-02

1. BACKGROUND

In May 2000, the SAE G-12 Holdover Time Subcommittee accepted new holdover times for Type I fluids. The reduced holdover time values were based on new Type I data obtained from tests conducted according to test protocols designed for Type II and IV fluids, which are applied to aircraft surfaces at ambient temperatures. Since Type I fluids are applied to an aircraft heated, the testing erroneously excluded the heat factor that provides Type I fluid much of its anti-icing properties. As a result, Type I holdover times were drastically reduced.

The reduced holdover times accepted for use by the SAE in 1999-2000 would likely require airlines currently using only Type I fluids to purchase millions of dollars worth of Type IV fluid application machinery, drastically increasing their annual anti-icing costs. Meanwhile, the 6-15 minute holdover time range for Type I fluids in snow has been used operationally for more than ten years.

In 2000-01 and 2001-02, the FAA and Transport Canada published the long-standing 6-15 minute Type I holdover time range in snow, but there is significant pressure to accept the more restrictive tables. Without data to support the continued use of the longer holdover times, the common industry practice of de-icing and anti-icing with only Type I fluid will likely perish.

Due to these problems, a new Type I fluid endurance time protocol is currently under development by APS. This new protocol will more closely simulate Type I anti-icing operations under natural conditions.

Following examination of several test surfaces and various procedures for fluid application, it was concluded that a 7.5 cm cold-soak box, empty, when treated with 0.5 L of fluid at 60°C, produced a reasonable representation of the temperature decay rate demonstrated by wings in natural outdoor conditions. A full account of these tests can be found in TP13827E Report, *SAE Type I Fluid Endurance Time Test Protocol*, October 2001.

2. OBJECTIVES

The purpose of the data collection at the Quebec City Airport (YQB) is to provide operational support data to assist in justifying or refuting the continued use of historical Type I fluid holdover times in snow (6 to 15 minutes).

To achieve this objective, a series of tests will be conducted to measure the endurance times of Type I fluids on the cold-soak box surfaces, using a procedure that takes account of the contribution of heat and reflects real field operations. All Type I box tests will be conducted side-by-side with actual Type I de-icing and anti-icing events on operational aircraft for comparative purposes.

3. PROCEDURE/TEST REQUIREMENTS

Type I endurance time tests on cold-soak boxes will be conducted in conjunction with precipitation rate data collection and operational aircraft deicing activities. The precipitation rate and operational deicing activities will be performed by American Eagle personnel in Quebec City.

A 7.5 cm cold-soak box will be provided as the Type I endurance time test surface for the outdoor tests. The box should be placed on the test stand well in advance of the desired test period and allowed to cool to outdoor air temperature.

Prior to the start of the deicing operation on the aircraft, the operator should flush out the line and spray several litres of the Type I fluid into a small, clean bucket. From there, 0.5 litres of the fluid should be placed in a 0.5-litre thermos container and the lid sealed. The temperature of the test fluid should be recorded prior to closing the lid (the fluid temperature should be about 60°C).

At the start of the final-step anti-icing procedure on the aircraft, the test fluid should be applied to the cold-soak box through a spreader and the start time recorded. The spreader should remain warm at all times prior to the application process. Just before pouring, the box surface should be cleaned according to the following procedure:

- Clean the surface of all contamination with scraper and squeegee

Tests on the cold-soak boxes will be allowed to continue until the standard end condition has been achieved (snow contamination covering 1/3 of the plate surface). The failure time should be noted on the attached data form.

In order to have a more accurate representation of the holdover time obtained in real field deicing operations, the trials need to be performed at different temperatures and rates, over several snowstorms. An attempt will be made to collect twenty data points.

4. EQUIPMENT AND FLUIDS

4.1 Equipment

The following equipment is required for type I endurance time tests on cold-soak boxes at Quebec City:

- One 7.5 cm cold-soak box (empty)
- Glass thermometer
- Squeegee
- Scraper
- 0.5-litre thermos
- Spreader with 12 holes
- Pail

4.2 Fluids

The tests will be conducted using ethylene glycol-based Type I XL54 fluid provided by American Eagle personnel in Quebec.

5. PERSONNEL

One technician will be required for these trials.

6. DATA FORMS

One data from, the End Condition Data Form, will be required for these tests (Attachment I-1).

ATTACHMENT I-1
END CONDITION DATA FORM

Winter 2001-02

LOCATION: **DATE:**

OAT: ______°C

FLUID TEMPERATURE: ______°C

OTHER COMMENTS :

____

____

____

____

____

____

____

____

FAILURES CALLED BY : ______________ (PRINT) ______________ (SIGN)

***TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (h:min)**

Time of Fluid Application: ________ h:min

	Enter Failure Time		
FLUID NAME			
B1 B2 B3			
C1 C2 C3			
D1 D2 D3			
E1 E2 E3			
F1 F2 F3			

CALCULATED FAILURE TIME (MINUTES) ☐

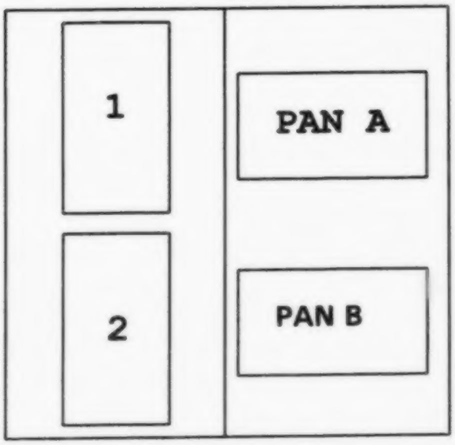
J

APPENDIX J

AMIL'S PROCEDURE FOR TYPE I TESTING

Procédures pour tests de neige

1. Identifier les plateaux ***(PAN A et PAN B)*** servant à la mesure de l'intensité de la neige.
   a) Verser du fluide de ***Type IV*** dans chaque PAN, juste assez pour recouvrir le fond. (utiliser n'importe quel fluide de Type IV disponible).
   b) Peser chaque PAN et remplir les lignes ***« Initial Weight »*** sur la feuille de calibration ***(Precipitation Rate Recording)***.
2. Nettoyer le support utilisé pour les tests, en prenant bien soin d'enlever la neige.
3. Les plaques de tests sont entreposées dans la boîte de plexiglas prévue à cette fin, afin qu'elles soient à température ambiante. Fixer la Cold Soak Box sur le support à l'aide des aimants et y déposer les plaques de tests, en prenant soin de faire correspondre le numéro de sonde avec la positon sur le schéma ci-dessous. Retirer les capuchons de protection sur les sondes et les conserver dans un endroit sûr. Connecter les sondes correspondantes (les numéros sont inscrits sur les fils). Inscrire la position des plaques et les sondes utilisées sur la feuille de test. ***(Plate position et Probe #)***.



Support des plaques

4. Selon la température de l'air inscrite à l'ordinateur, préparer deux échantillons avec la dilution adéquate du fluide à utiliser ***(2 X 500 ml)*** en consultant le tableau mis à votre disposition et les faire chauffer jusqu'à ***60°C*** en prenant bien soin d'ouvrir la hotte à l'intérieur de la cabane. Faire attention d'utiliser les bons cylindres gradués pour éviter toute contamination.
5. Noter la température de l'air, la position et la dilution du fluide aux endroits appropriés sur la feuille de tests ***(Anti-Icing Endurance Time Recording)***.

6. Avant de commencer le test, attendre que la température de l'air soit sensiblement ***la même*** que celle des plaques.
7. Déposer les PANS A et B sur le support en laissant les couvercles.
8. Démarrer le système d'acquisition de données, noter l'heure précise sur l'horloge à ce moment ***(Day time when starting computer)***.
9. Retirer le couvercle de la PAN A et démarrer le chronomètre. Noter l'heure exacte de l'horloge à ce moment ***(Day time when starting snow collect)***.
10. Enlever la neige sur la première plaque et verser, avec le système de distribution, ***500 ml*** de fluide sur la plaque de test, finir le bécher en versant dans le haut de la plaque. Démarrer le second chronomètre à la fin de l'application seulement. Noter l'heure de l'horloge à ce moment. ***(Day time at start)***.
11. Enlever la neige sur la seconde plaque et verser, avec le système de distribution, l'autre ***500 ml*** du même fluide sur la plaque de test, finir la bouteille en versant dans le haut de la plaque. Démarrer le troisième chronomètre à la fin de l'application seulement. Noter l'heure de l'horloge à ce moment. ***(Day time at start)***.
12. Exactement ***5 minutes*** après avoir démarré le premier chronomètre (celui de la calibration), couvrir la PAN A et découvrir la PAN B. Peser la PAN A et noter le poids sur la feuille prévue à cet effet ***(Precipitation Rate Recording)***. Remettre la PAN A sur le support, en laissant le couvercle.
13. Exactement ***10 minutes*** après avoir démarrer le premier chronomètre (celui de la calibration), retirer le couvercle de la PAN A et le déposer sur la PAN B. Peser la PAN B et noter le poids sur la feuille de test ***(Precipitation Rate Recording)***. Remettre la PAN B sur le support en laissant le couvercle. Répéter cette opération, en alternant les PANS A et B, à toutes les 5 minutes.
14. Déterminer la direction et la vitesse du vent et les noter sur la feuille de test ***(Wind direction et Wind speed)***, au début du test et chaque fois qu'elle change de façon significative, avec l'heure à laquelle elle a été déterminée.
15. En laissant tomber des flocons sur le plateau de feutre noir, déterminer le type et la grosseur des flocons. Noter ces différentes caractéristiques dans les cases prévues ***(Precipitation Rate Recording)***. Si les flocons semblent changer pendant un même événement de neige, reprendre les différentes caractéristiques et noter l'heure du changement.
16. Remplir les feuilles de test très attentivement
    a) Numéroter les tests en ordre chronologique, en donnant le numéro de test pour un événement de neige donné ***(OS2-XXX)***, O pour Outdoor, S pour Snow, 2 pour l'année 2002 et XXX pour le numéro chronologique du test.

b) Si plusieurs tests de fluide sont faits pendant un même événement de neige, le ***numéro de tests ne change pas*** et le ***système d'acquisition de données doit demeurer en marche***. Changer de numéro de tests chaque fois que les opérateurs changent ou à chaque nouvel événement.

c) Prendre soin de toujours noter l'***heure*** à laquelle un test commence.

17. Prendre une photo ***(une à chaque événement)*** de chaque fluide, sans flash, ***à l'échec*** soit quand 30% de la plaque est recouverte de neige blanche. Noter sur la feuille de test le numéro de la photo. Noter le temps exact sur le chronomètre au moment de l'échec ***(rectangle 30% white snow, Failure)***.

18. Nettoyer à l'eau déminéralisée puis, à l'éthanol ***tout le matériel*** incluant les cylindres gradués et entreposer les plaques dans la boîte prévue à cet effet, à l'extérieur de la cabane afin qu'elles soient prêtes à utiliser par l'équipe suivante.

19. S'assurer que les feuilles de tests sont remplies adéquatement avant de les remettre au responsable du projet. (Nathalie Gagné)

20. S'assurer de toujours avoir assez de fluide dans les bouteilles de 4 litres et assez d'eau déminéralisée pour les prochains tests de neige.

Numéros de téléphone

Noms	**Téléphone (maison)**	**UQAC**
Caroline Blackburn	549-7789	2271
Martin Truchon	696-3234	2137
Nathalie Gagné	548-6939 (paget 591-5735)	2190
Xiaofei Wang	693-6074	2340 ou 2342

K

APPENDIX K

TYPE I FLUID FREEZE POINT AND TEMPERATURE DECAY CHARTS 2001-02 NATURAL SNOW TESTING

Type I Fluid Natural Snow Test Log of All Fluid Freeze Point Charts

Test no.	Date	Run no.	Fluid Name	Surface	FFP @ Failure (°C)	Fail Time [min.]	AVG PAN [$g/dm^2/h$]	READAC Data		DATA	CHART	RATE
								temp [C]	Wind Sp [km/h]			
18	Jan-15-02	2	PG	Box	-7.5	71.9	0.9	-7.6	25.2	X	X	X
23	Jan-15-02	3	PG	Box	-5.3	50.3	2.1	-7.1	24.0	X	X	X
24	Jan-15-02	3	XL55	Box	-5.8	50.0	2.1	-7.1	24.0	X	X	X
27	Jan-15-02	4	EG	Box	-5.0	65.7	1.3	-6.4	23.4	X	X	X
29	Jan-15-02	4	XL54	Box	-5.7	64.5	1.3	-6.4	23.4	X	X	X
30	Jan-15-02	5	EG	Plate	-3.8	9.6	6.2	-5.2	18.9	X	X	X
32	Jan-15-02	5	EG	Box	-3.1	13.5	6.2	-5.2	19.2	X	X	X
37	Jan-15-02	6	EG	Box	-3.8	14.4	5.1	-5.1	21.7	X	X	X
42	Jan-15-02	7	EG	Box	-2.3	11.9	8.2	-5.0	17.0	X	X	X
43	Jan-15-02	7	PG	Box	-2.2	11.0	8.3	-5.0	17.0	X	X	X
44	Jan-15-02	7	XL55	Box	-2.8	11.1	8.7	-5.0	17.3	X	X	X
45	Jan-17-02	1	XL54	Box	-4.3	18.7	3.3	-4.9	19.9	X	X	X
47	Jan-17-02	1	EG	Box	-4.3	15.3	3.1	-4.9	20.0	X	X	X
49	Jan-17-02	1	EG	Plate	-3.8	10.5	2.5	-5.0	19.4	X	X	X
50	Jan-17-02	2	XL55	Box	-4.6	23.3	2.5	-4.9	21.6	X	X	X
51	Jan-17-02	2	PG	Box	-4.2	19.5	2.5	-4.9	21.6	X	X	X
53	Jan-17-02	2	PG	Plate	-5.3	10.9	2.6	-4.9	22.2	X	X	X
67	Jan-17-02	5	EG	Box	0.0	12.4	9.7	-3.2	7.9	X	X	X
72	Jan-17-02	6	EG	Box	-2.0	14.4	4.0	-4.8	12.8	X	X	X
77	Jan-17-02	7	EG	Box	-4.7	9.7	9.8	-7.0	17.8	X	X	X
80	Jan-21-02	1	XL54	Box	0.0	23.5	4.8	-1.4	0.0	X	X	X
81	Jan-21-02	1	PG	Box	-0.5	26.8	4.4	-1.4	0.0	X	X	X
82	Jan-21-02	1	EG	Box	-0.5	26.9	4.3	-1.4	0.1	X	X	X
85	Jan-21-02	2	XL55	Box	-1.7	33.5	2.1	-1.7	5.5	X	X	X
86	Jan-21-02	2	PG	Box	-1.6	30.5	2.2	-1.7	5.3	X	X	X
88	Jan-21-02	2	PG	Plate	-2.8	14.2	2.8	-1.7	4.9	X	X	X
90	Jan-31-02	1	XL54	Box	-11.0	11.4	7.6	-13.8	25.8	X	X	X
92	Jan-31-02	1	EG	Box	-12.0	8.8	7.2	-13.8	25.6	X	X	X
94	Jan-31-02	1	EG	Plate	-13.0	5.5	5.1	-13.9	25.4	X	X	X
95	Jan-31-02	2	XL55	Box	-11.3	12.9	5.1	-13.8	25.3	X	X	X
96	Jan-31-02	2	PG	Box	-10.5	10.5	5.0	-13.8	25.1	X	X	X
98	Jan-31-02	2	PG	Plate	-9.5	6.8	4.7	-13.8	25.2	X	X	X
100	Jan-31-02	3	XL54	Box	-16.3	15.8	3.9	-13.8	27.5	X	X	X
102	Jan-31-02	3	EG	Box	-12.0	10.7	3.9	-13.8	28.4	X	X	X
104	Jan-31-02	3	EG	Plate	-13.5	7.3	3.6	-13.8	29.2	X	X	X
105	Jan-31-02	3A	XL55	Box	-12.5	18.0	4.1	-13.6	26.3	X	X	X
106	Jan-31-02	3A	PG	Box	-12.5	12.2	4.7	-13.6	25.5	X	X	X
107	Jan-31-02	3A	PG	Plate	-12.5	7.7	5.0	-13.6	24.9	X	X	X
108	Feb-3-02	1	XL54	Box	-3.4	13.9	4.6	-9.1	7.9	X	X	X
109	Feb-3-02	1	EG	Box	-3.0	12.7	4.5	-9.1	7.9	X	X	X
110	Feb-3-02	1	EG	Plate	-4.2	9.7	4.2	-9.1	7.8	X	X	X
111	Feb-3-02	2	XL55	Box	-2.2	13.0	7.5	-8.1	11.4	X	X	X

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\snowlog table

Type I Fluid Natural Snow Test Log of All Fluid Freeze Point Charts

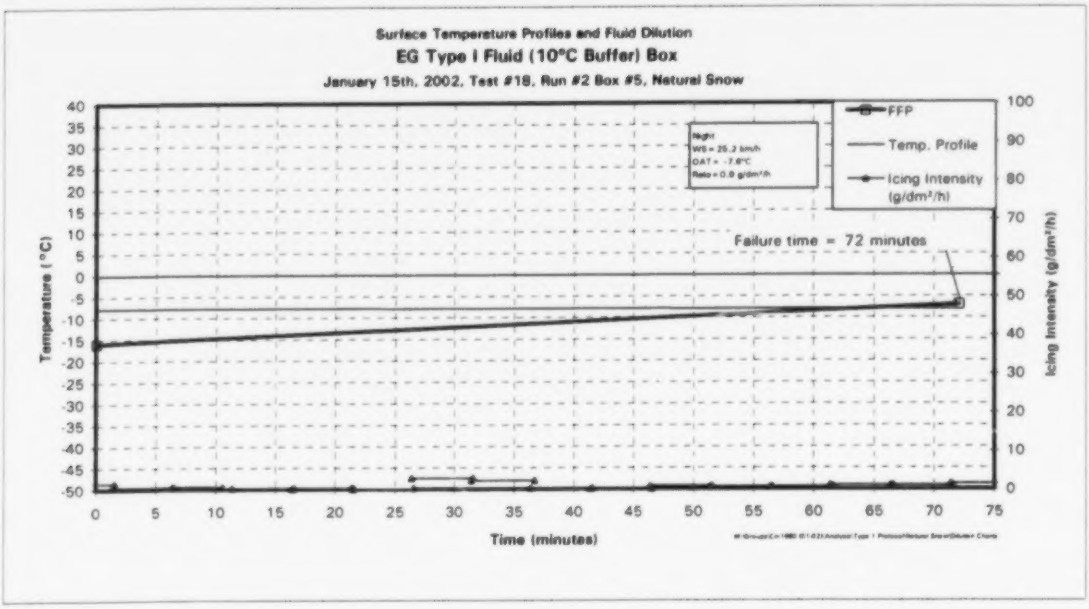
Test no.	Date	Run no.	Fluid Name	Surface	FFP @ Failure (°C)	Fail Time [min.]	AVG PAN [g/dm²/h]	READAC Data		DATA	CHART	RATE
								temp [°C]	Wind Sp [km/h]			
112	Feb-3-02	2	PG	Box	-2.2	10.5	7.3	-8.1	11.4	X	X	X
114	Feb-3-02	2	PG	Plate	-4.2	7.3	7.2	-8.1	11.6	X	X	X
116	Feb-3-02	3	XL54	Box	-2.0	36.1	1.2	-5.3	13.3	X	X	X
118	Feb-3-02	3	EG	Box	-4.3	33.1	1.2	-5.3	13.1	X	X	X
120	Feb-3-02	3	EG	Plate	-3.4	18.0	1.4	-5.4	12.4	X	X	X
121	Feb-3-02	3A	XL55	Box	-3.0	37.4	1.6	-4.5	13.4	X	X	X
122	Feb-3-02	3A	PG	Box	-3.8	37.3	1.6	-4.5	13.4	X	X	X
123	Feb-3-02	3A	PG	Plate	-3.8	28.0	0.9	-4.5	13.0	X	X	X
124	Feb-3-02	3B	XL54	Box	-4.3	16.4	4.1	-7.2	19.1	X	X	X
125	Feb-3-02	3B	EG	Box	-3.7	12.5	3.3	-7.3	19.0	X	X	X
126	Feb-3-02	3B	EG	Plate	-5.0	8.6	3.4	-7.2	18.7	X	X	X
127	Feb-3-02	4	XL55	Box	-5.2	14.7	4.7	-8.2	15.7	X	X	X
129	Feb-3-02	4	PG	Box	-5.7	13.8	4.9	-8.2	15.8	X	X	X
131	Feb-3-02	4	PG	Plate	-5.8	8.8	4.7	-8.2	15.9	X	X	X
132	Feb-3-02	5	XL54	Box	-6.5	12.9	4.7	-8.6	14.2	X	X	X
133	Feb-3-02	5	PG	Box	-5.8	9.3	5.5	-8.6	14.3	X	X	X
134	Feb-3-02	5	EG	Box	-6.0	10.3	4.9	-8.6	14.5	X	X	X
135	Feb-3-02	5	PG	Plate	-7.5	7.0	5.6	-8.6	14.4	X	X	X
136	Feb-3-02	5	EG	Plate	-7.3	7.1	5.3	-8.6	14.4	X	X	X
137	Feb-3-02	6	XL54	Box	-5.3	9.3	7.7	-9.2	12.6	X	X	X
138	Feb-3-02	6	PG	Box	-5.2	8.0	7.7	-9.2	12.6	X	X	X
139	Feb-3-02	6	EG	Box	-4.8	7.7	7.6	-9.2	12.5	X	X	X
140	Feb-3-02	6	PG	Plate	-5.4	4.9	7.8	-9.2	13.0	X	X	X
141	Feb-3-02	6	EG	Plate	-8.2	5.6	7.6	-9.2	12.7	X	X	X
142	Feb-10-02	1	XL54	Box	-3.5	19.2	16.1	-2.8	43.2	X	X	X
143	Feb-10-02	1	PG	Box	-4.6	16.6	16.8	-2.8	43.0	X	X	X
144	Feb-10-02	1	EG	Box	-3.1	13.7	17.7	-2.8	42.1	X	X	X
145	Feb-10-02	1	PG	Plate	-4.3	9.3	20.2	-2.7	40.9	X	X	X
146	Feb-10-02	1	EG	Plate	-4.3	7.5	22.5	-2.8	41.0	X	X	X
150	Feb-10-02	2	PG	Plate	-5.3	4.9	20.1	-4.7	47.5	X	X	X
152	Feb-10-02	3	XL54	Box	-7.0	52.4	2.0	-5.6	29.5	X	X	X
153	Feb-10-02	3	EG	Box	-6.9	49.0	2.0	-5.6	29.8	X	X	X
154	Feb-10-02	3	EG	Plate	-6.5	20.8	1.8	-5.5	32.9	X	X	X
155	Feb-10-02	4	PG	Plate	-7.0	12.3	2.9	-6.1	22.5	X	X	X
157	March-18-02	1	PG	Box		16.6	15.6	-0.7	21.4	X	X	X
158	March-18-02	1	PG	Plate		7.8	14.3	-0.8	21.1	X	X	X
159	March-18-02	1	EG	Plate		8.3	14.8	-0.8	21.3	X	X	X
161	March-18-02	3	XL54	Box		8.8	35.8	-0.5	26.1	X	X	X
162	March-18-02	3	PG	Box		9.4	33.2	-0.5	25.4	X	X	X
163	March-18-02	3	EG	Box		9.7	31.6	-0.5	24.7	X	X	X
164	March-18-02	3	PG	Plate		5.6	32.8	-0.5	25.4	X	X	X

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\snowlog table

Type I Fluid Natural Snow Test Log of All Fluid Freeze Point Charts

Test no.	Date	Run no.	Fluid Name	Surface	FFP @ Failure (°C)	Fail Time [min.]	AVG PAN [g/dm^2/h]	READAC Data		DATA	CHART	RATE
								temp [°C]	Wind Sp [km/h]			
165	March-18-02	3	EG	Plate		5.3	30.8	-0.5	25.0	X	X	X
167	March-18-02	5	XL54	Box		6.7	40.5	-0.5	22.0	X	X	X
168	March-18-02	5	PG	Box		9.4	41.9	-0.5	20.9	X	X	X
170	March-18-02	5	PG	Plate		3.5	41.6	-0.5	23.2	X	X	X
173	March-18-02	8	XL54	Box		10.7	25.9	-0.7		X	X	X
175	March-18-02	8	EG	Box		11.7	27.5	-0.7		X	X	X
177	March-18-02	8	EG	Plate		6.5	28.4	-0.7		X	X	X
178	March-18-02	9	XL54	Box		7.7	33.4	-0.6		X	X	X
179	March-18-02	9	PG	Box		6.9	33.0	-0.6		X	X	X
181	March-18-02	9	PG	Plate		4.3	31.5	-0.6		X	X	X
185	March-18-02	10	XL54	Box		11.1	21.9	-0.6		X	X	X
187	March-18-02	10	EG	Box		10.7	21.7	-0.6		X	X	X
189	March-18-02	10	EG	Plate		6.2	21.5	-0.6		X	X	X
191	March-18-02	11	XL54	Box		10.5	22.4	-0.8		X	X	X
192	March-18-02	11	PG	Box		10.3	21.7	-0.8		X	X	X
194	March-18-02	11	PG	Plate		5.8	22.9	-0.8		X	X	X
196	March-18-02	12	XL54	Box		12.0	21.1	-0.9	31.8	X	X	X
198	March-18-02	12	EG	Box		10.2	20.8	-0.9	31.5	X	X	X
200	March-18-02	12	EG	Plate		6.2	16.3	-0.9	30.2	X	X	X
203	March-18-02	13	XL54	Box		7.0	31.5	-1.0	32.6	X	X	X
204	March-18-02	13	PG	Box		6.6	31.1	-1.0	32.8	X	X	X
206	March-18-02	13	PG	Plate		3.5	31.3	-1.0	32.6	X	X	X
208	March-18-02	14	XL54	Box		9.8	20.8	-1.2	30.3	X	X	X
210	March-18-02	14	EG	Box		9.1	20.2	-1.2	30.4	X	X	X
212	March-18-02	14	EG	Plate		4.8	20.5	-1.2	30.2	X	X	X
220	March-20-02	2	PG	Box		8.0	29.2	0.2	20.0	X	X	X
222	March-20-02	2	PG	Plate		4.0	33.0	0.2	20.0	X	X	X
226	March-20-02	3	EG	Box		9.5	31.9	0.3	16.8	X	X	X
228	March-20-02	3	EG	Plate		4.9	31.2	0.3	15.7	X	X	X
230	March-20-02	6	PG	Box		10.8	21.6	0.3	22.1	X	X	X
232	March-20-02	6	PG	Plate		4.6	21.0	0.4	21.0	X	X	X

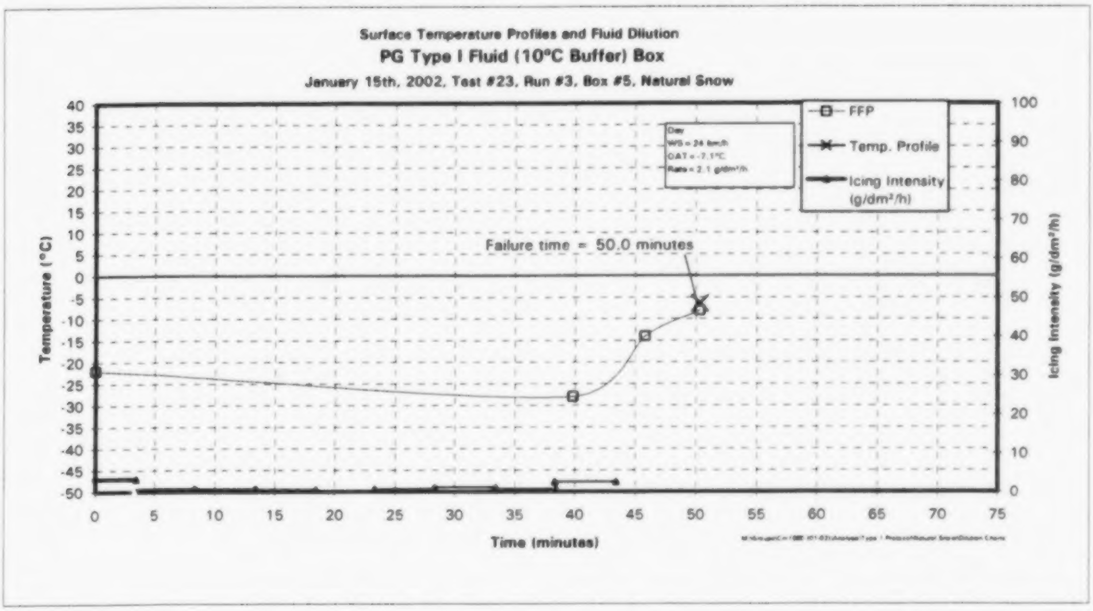
M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\snowlog table



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

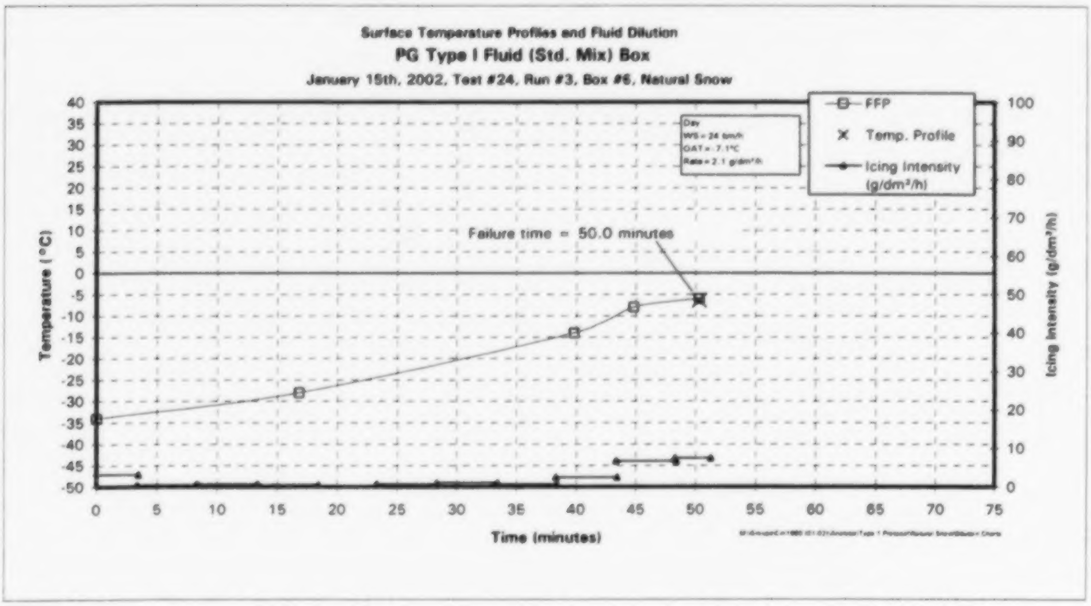
January 15th, 2002, Test #18, Run #2 Box #5, Natural Snow

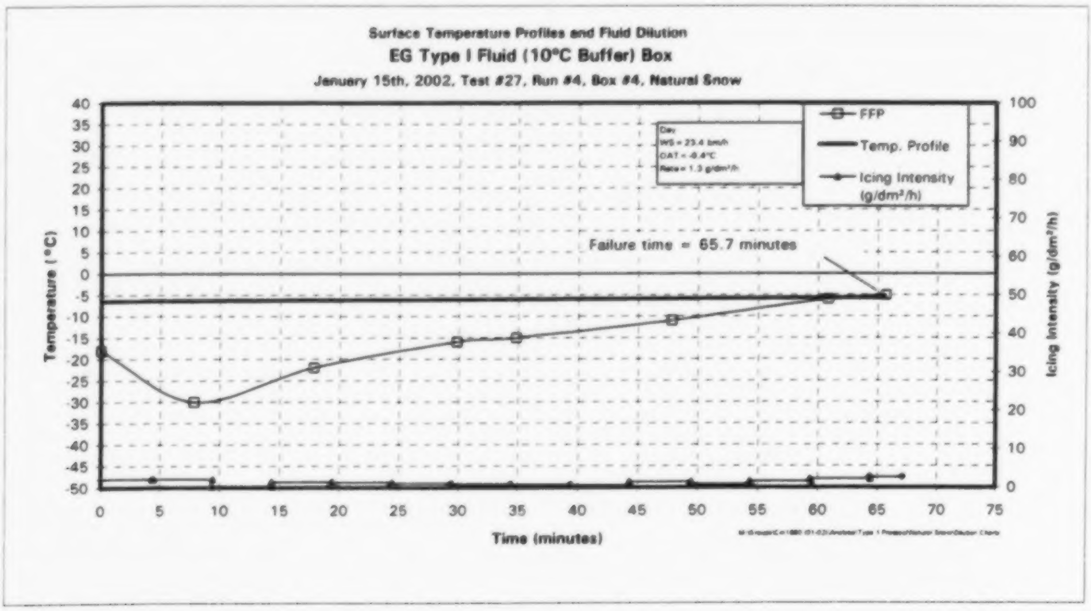


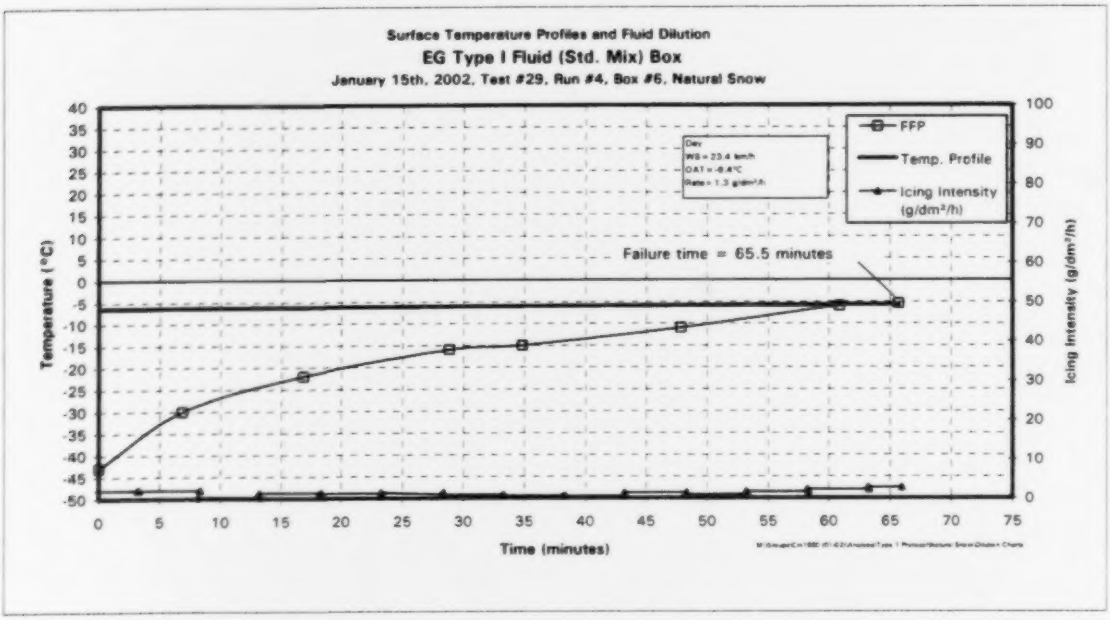
Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

January 15th, 2002, Test #23, Run #3, Box #5, Natural Snow


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (Std. Mix) Box
January 15th, 2002, Test #24, Run #3, Box #6, Natural Snow

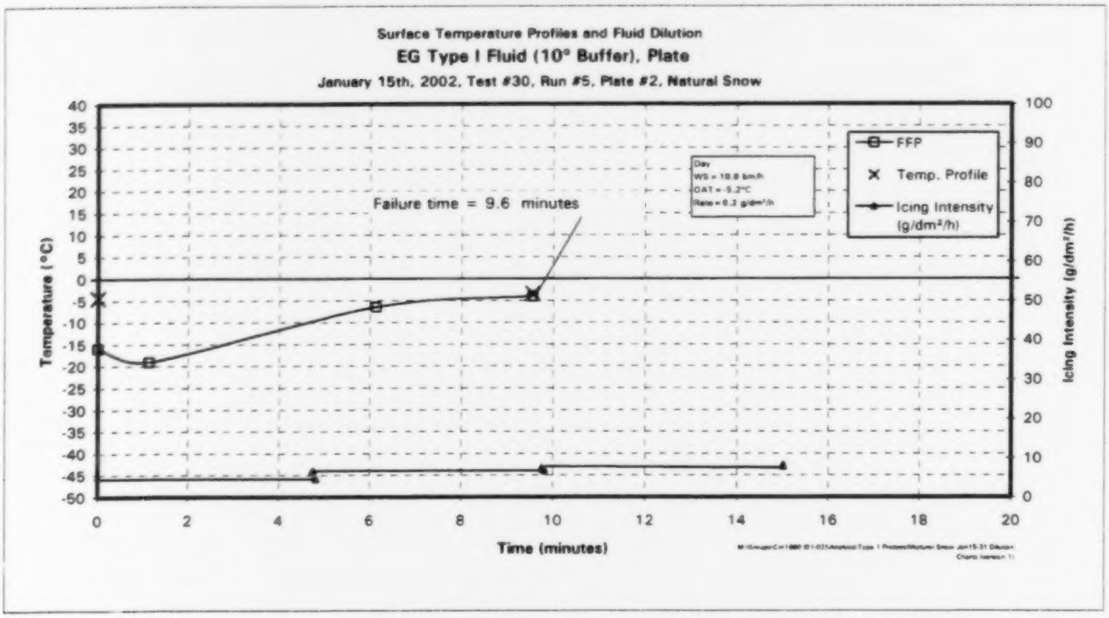

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
January 15th, 2002, Test #27, Run #4, Box #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

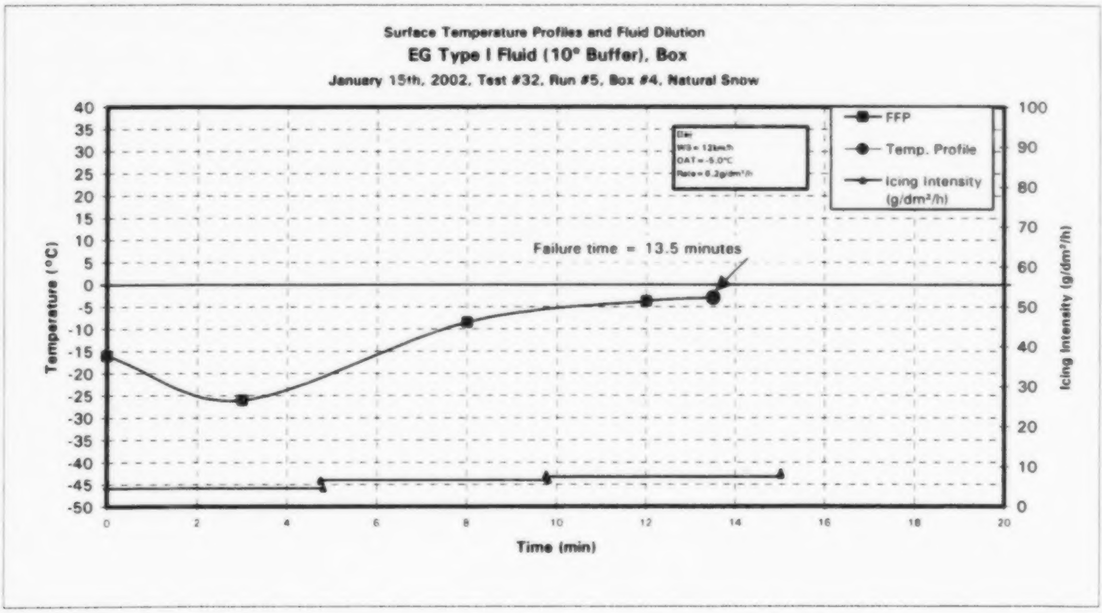
January 15th, 2002, Test #29, Run #4, Box #6, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10° Buffer), Plate

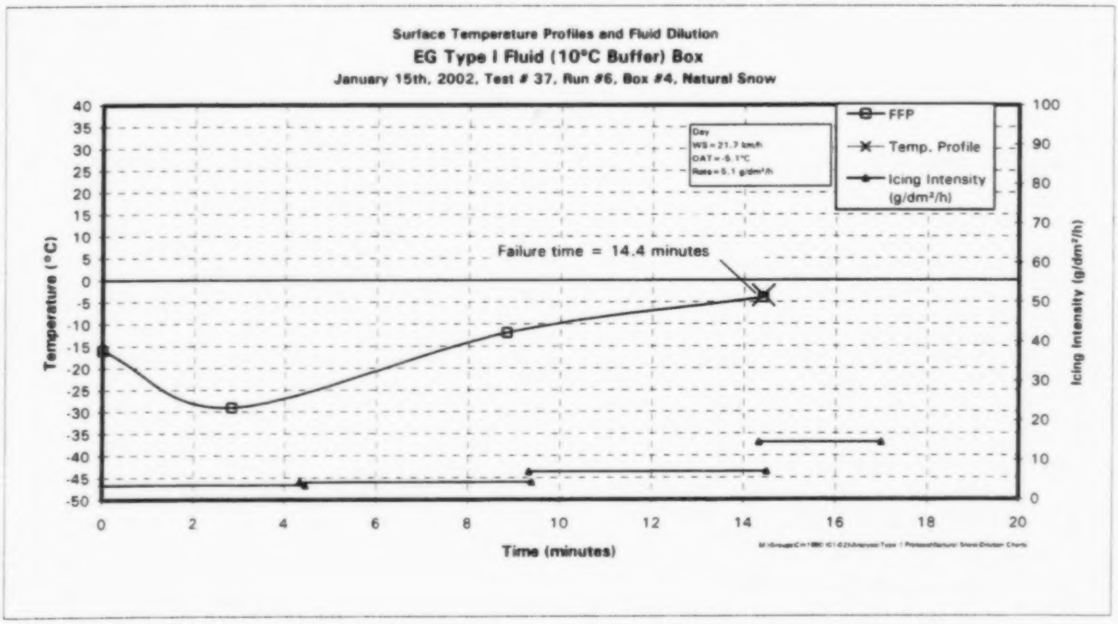
January 15th, 2002, Test #30, Run #5, Plate #2, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10° Buffer), Box

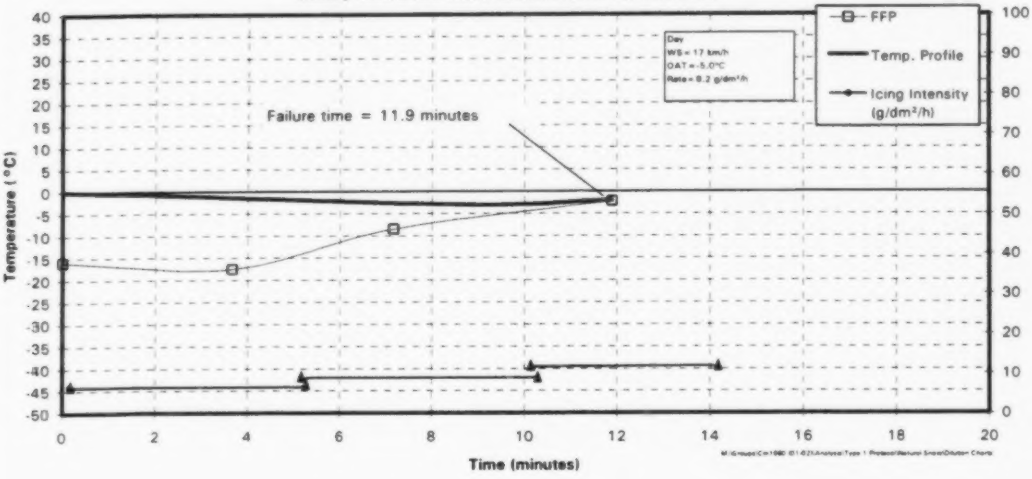
January 15th, 2002, Test #32, Run #5, Box #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

January 15th, 2002, Test # 37, Run #6, Box #4, Natural Snow

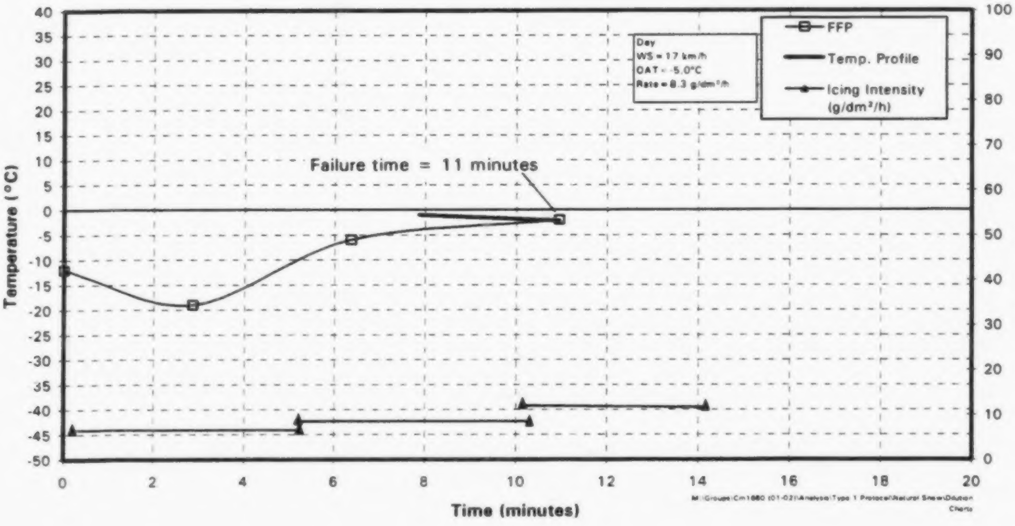


Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

January 15th, 2002, Test #42, Run #7, Box #3, Natural Snow

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\Natural Snow\Dilution Charts

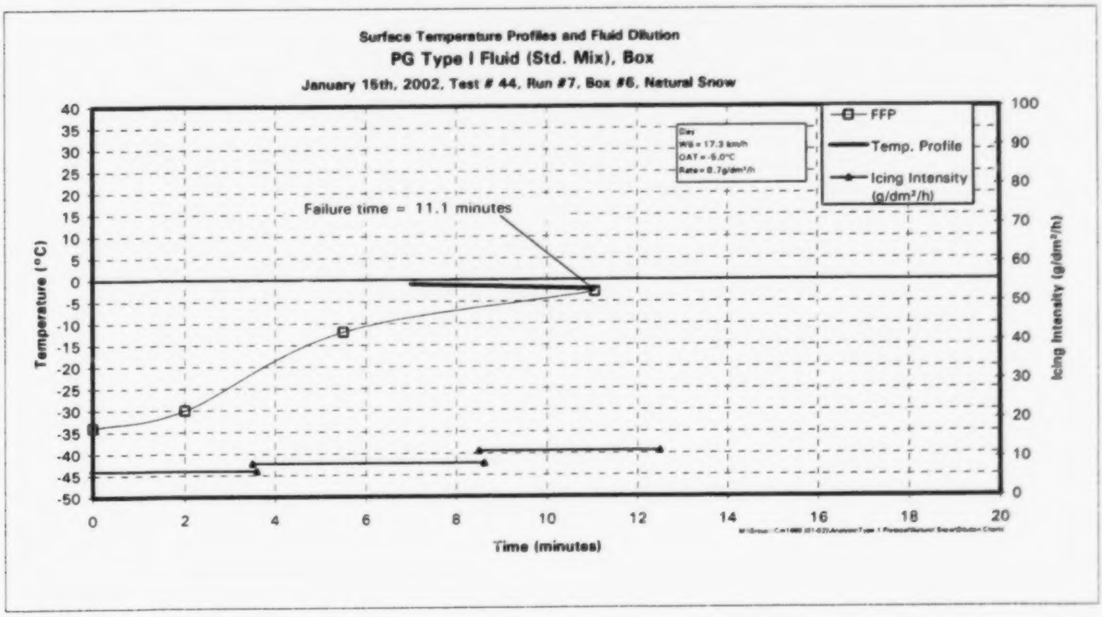


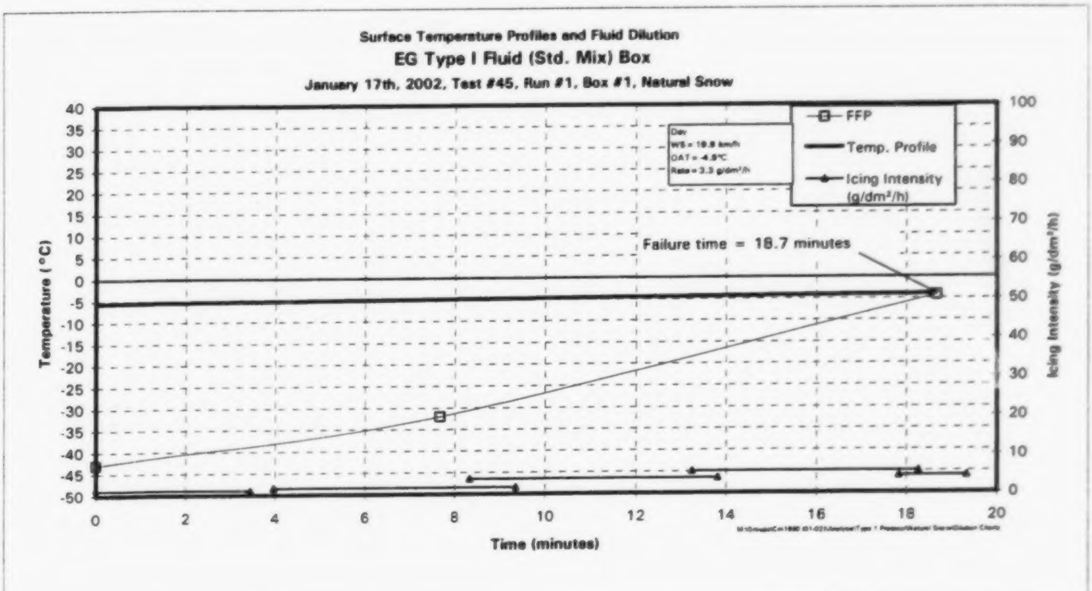
Surface Temperature Profiles and Fluid Dilution

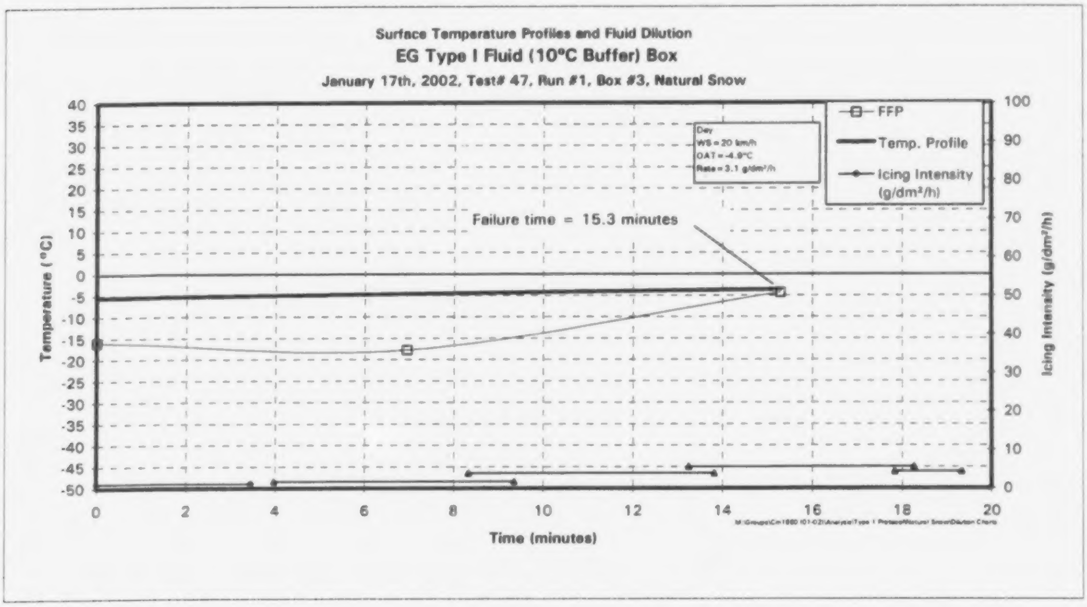
PG Type I Fluid (10°C Buffer) Box

January 15th, 2002, Test #43, Run #7, Box #5, Natural Snow

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\Natural Snow\Dilution Charts


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (Std. Mix), Box
January 15th, 2002, Test # 44, Run #7, Box #6, Natural Snow
Day
WS = 17.3 km/h
OAT = -5.0°C
Rate = 8.7g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 11.1 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
Time (minutes)


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
January 17th, 2002, Test #45, Run #1, Box #1, Natural Snow
Day
WS = 19.8 km/h
OAT = -4.5°C
Rate = 3.3 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 18.7 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
Time (minutes)

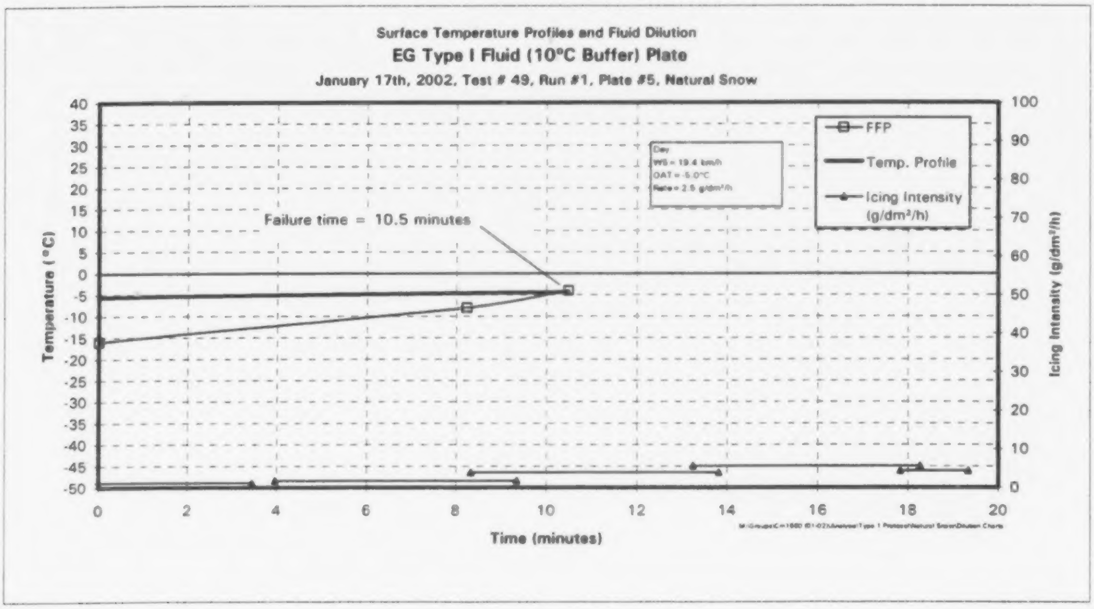


Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

January 17th, 2002, Test# 47, Run #1, Box #3, Natural Snow

Failure time = 15.3 minutes

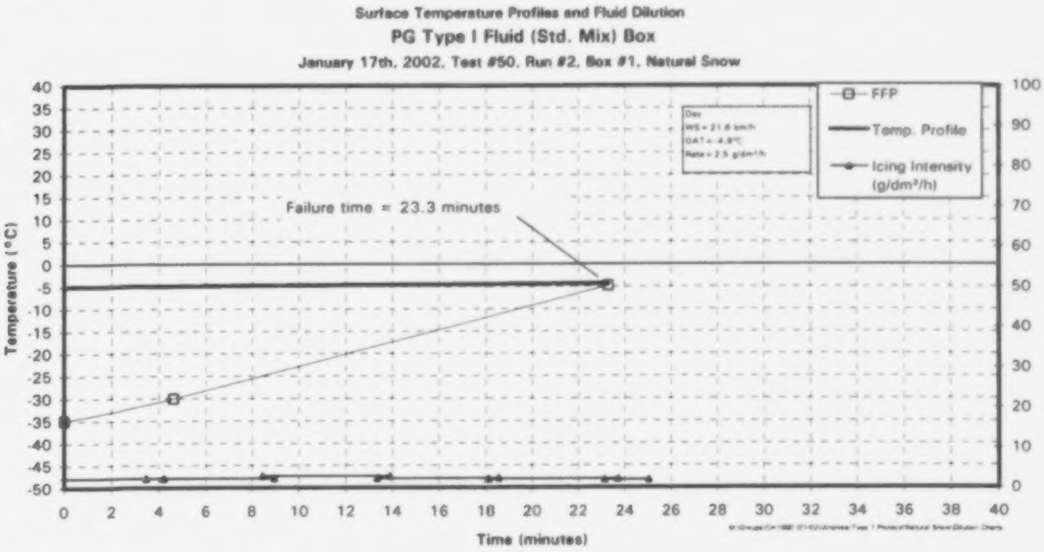


Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

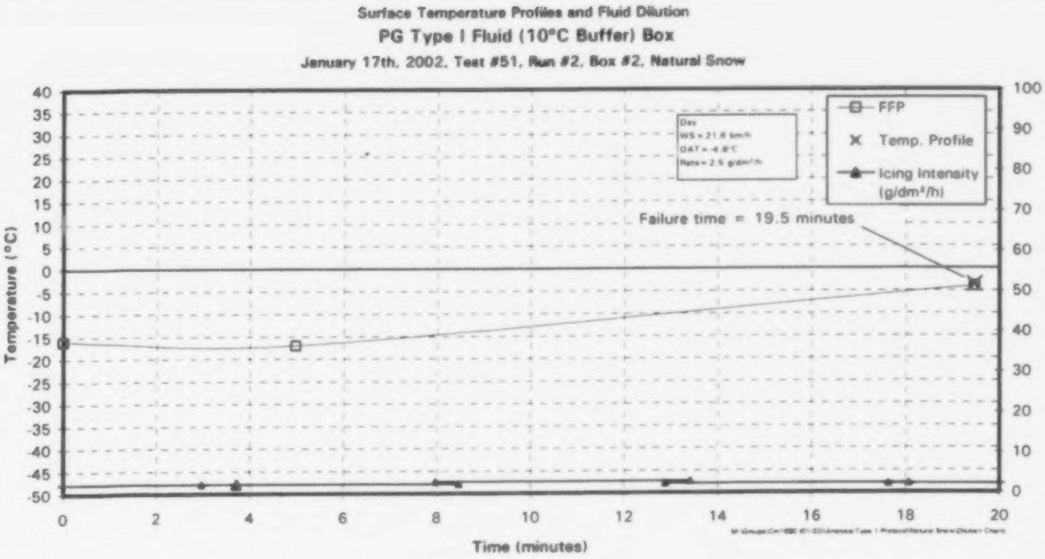
January 17th, 2002, Test # 49, Run #1, Plate #5, Natural Snow

Failure time = 10.5 minutes


Surface Temperature Profiles and Fluid Dilution

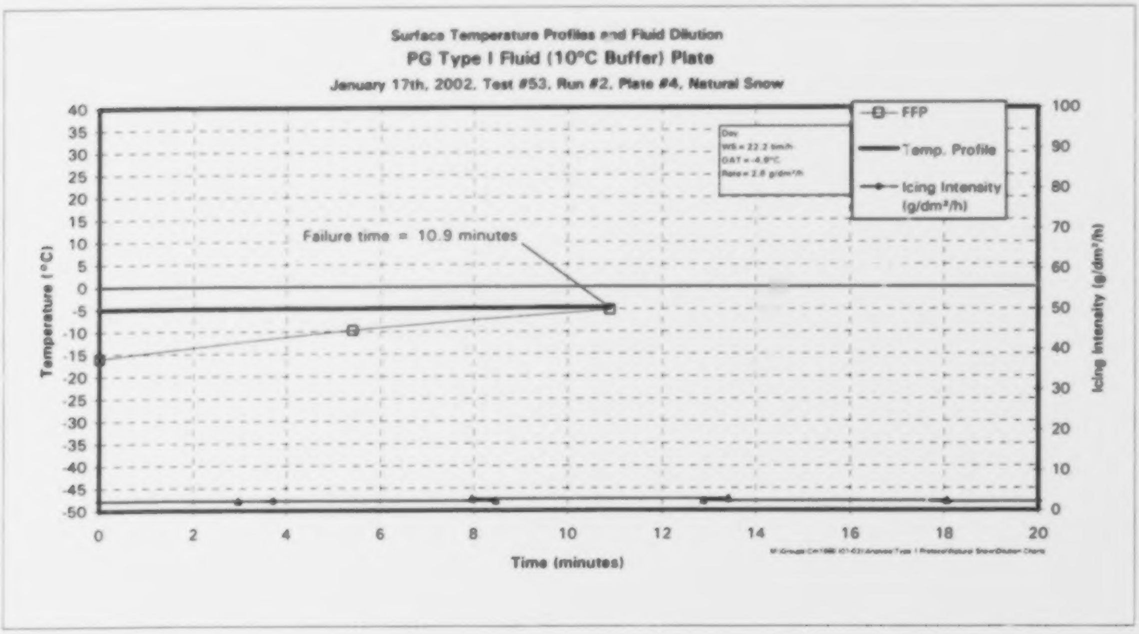
PG Type I Fluid (Std. Mix) Box

January 17th, 2002, Test #50, Run #2, Box #1, Natural Snow


Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

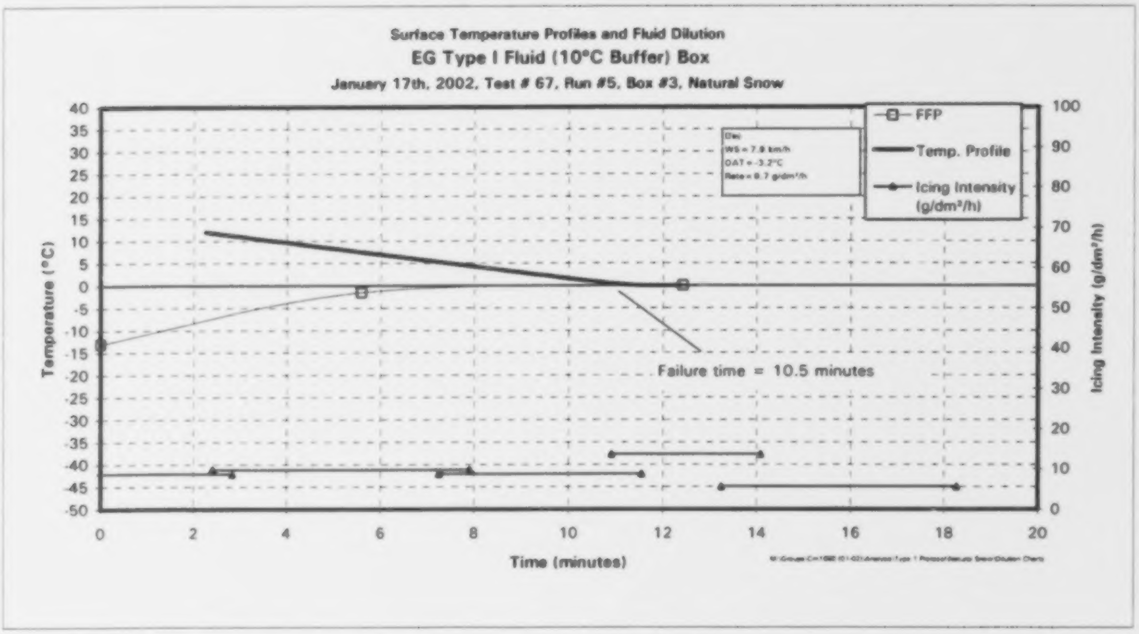
January 17th, 2002, Test #51, Run #2, Box #2, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

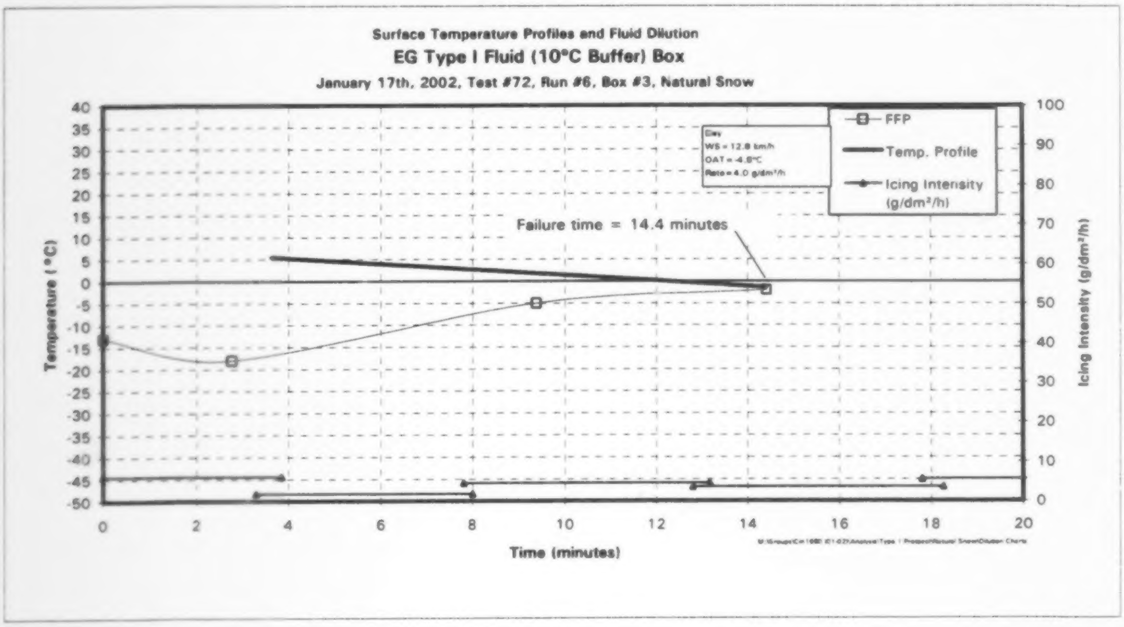
January 17th, 2002, Test #53, Run #2, Plate #4, Natural Snow

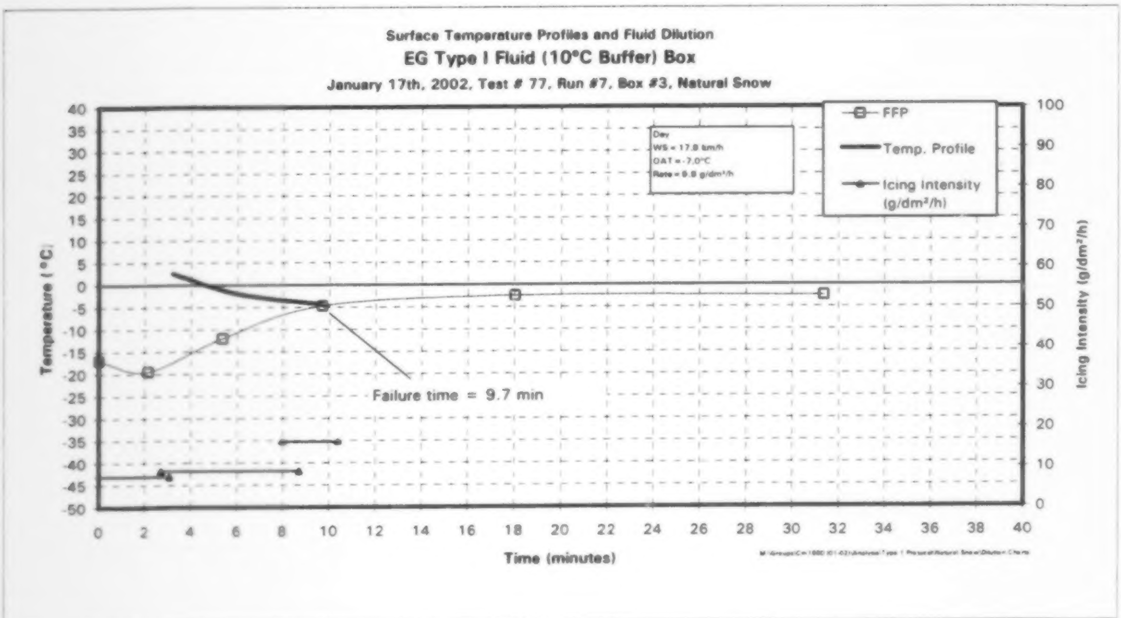


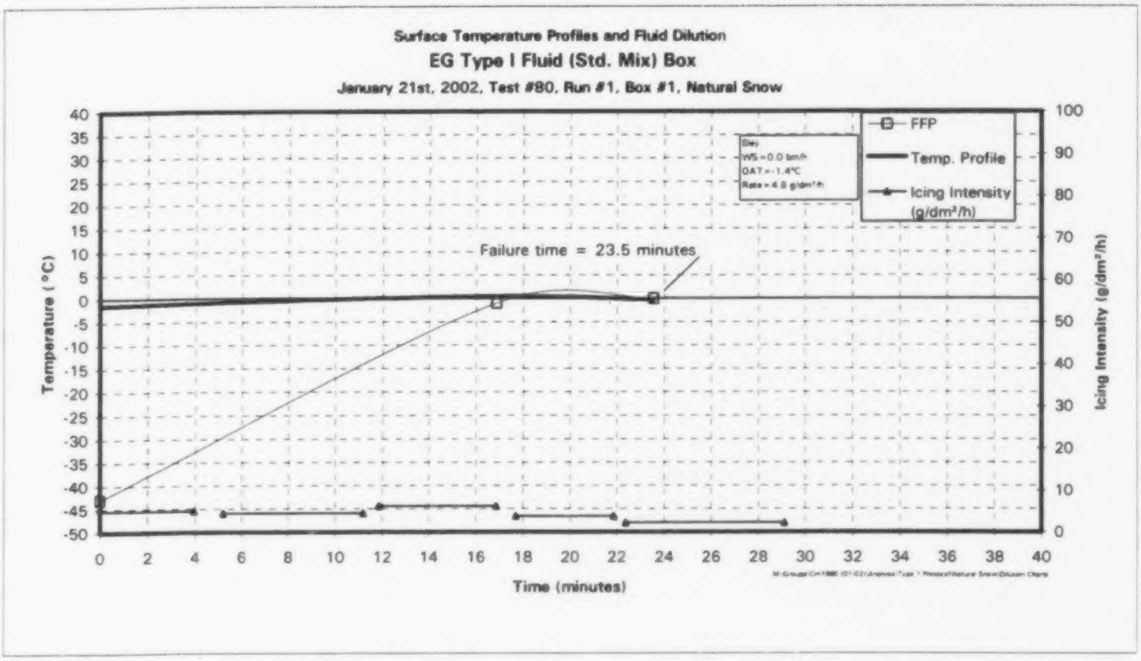
Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

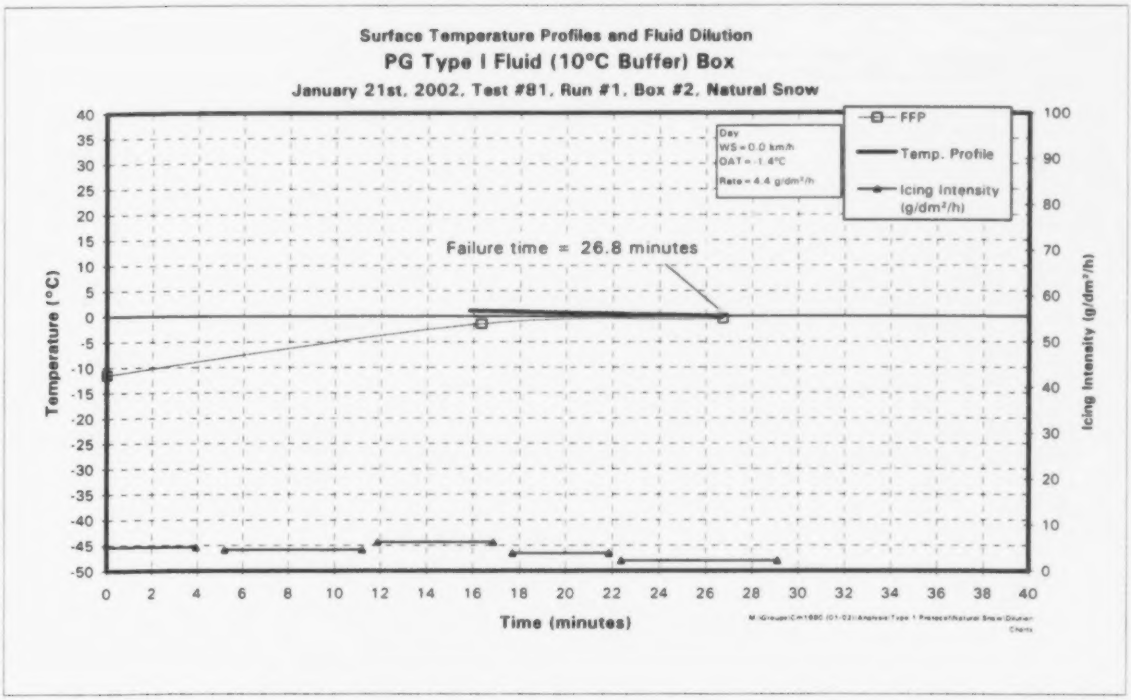
January 17th, 2002, Test # 67, Run #5, Box #3, Natural Snow


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
January 17th, 2002, Test #72, Run #6, Box #3, Natural Snow

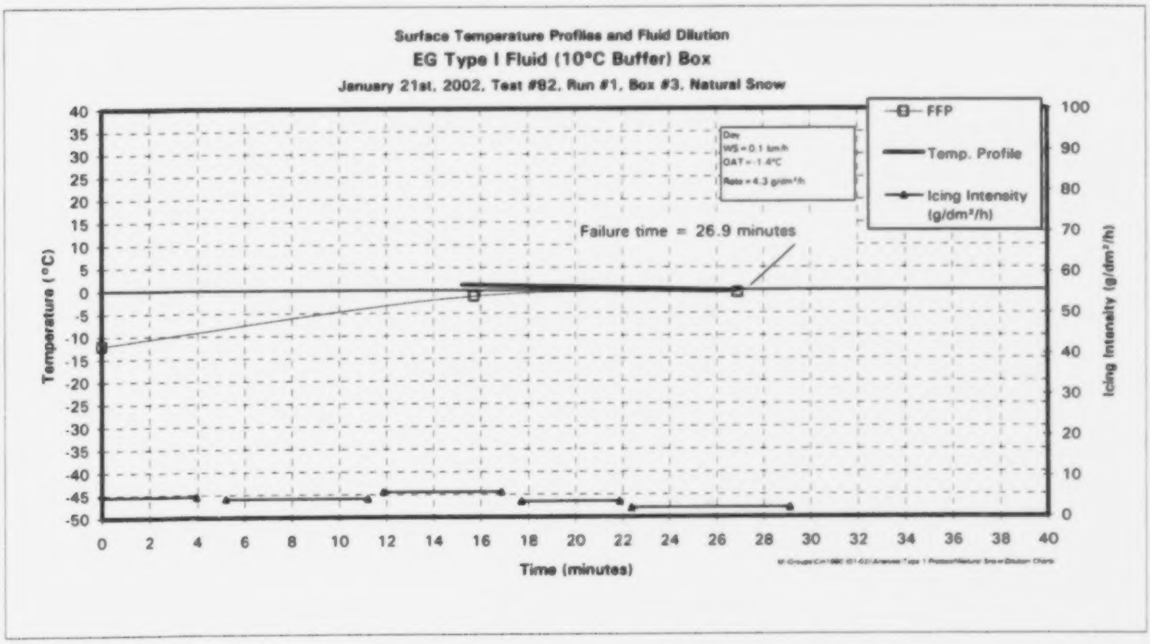

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
January 17th, 2002, Test # 77, Run #7, Box #3, Natural Snow

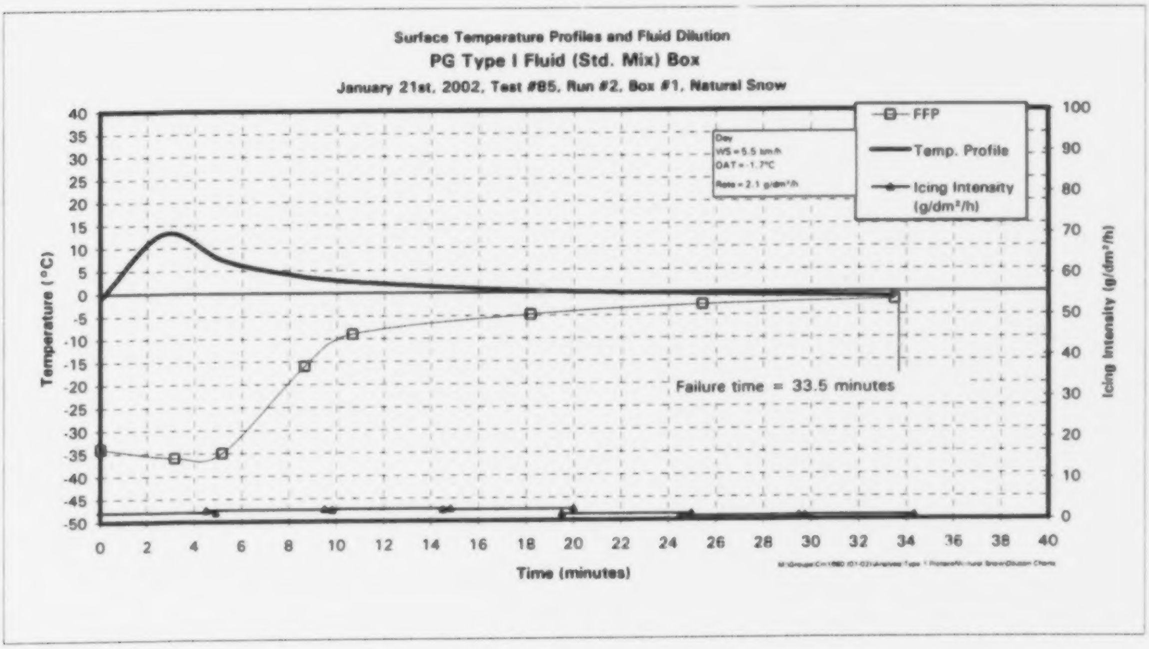


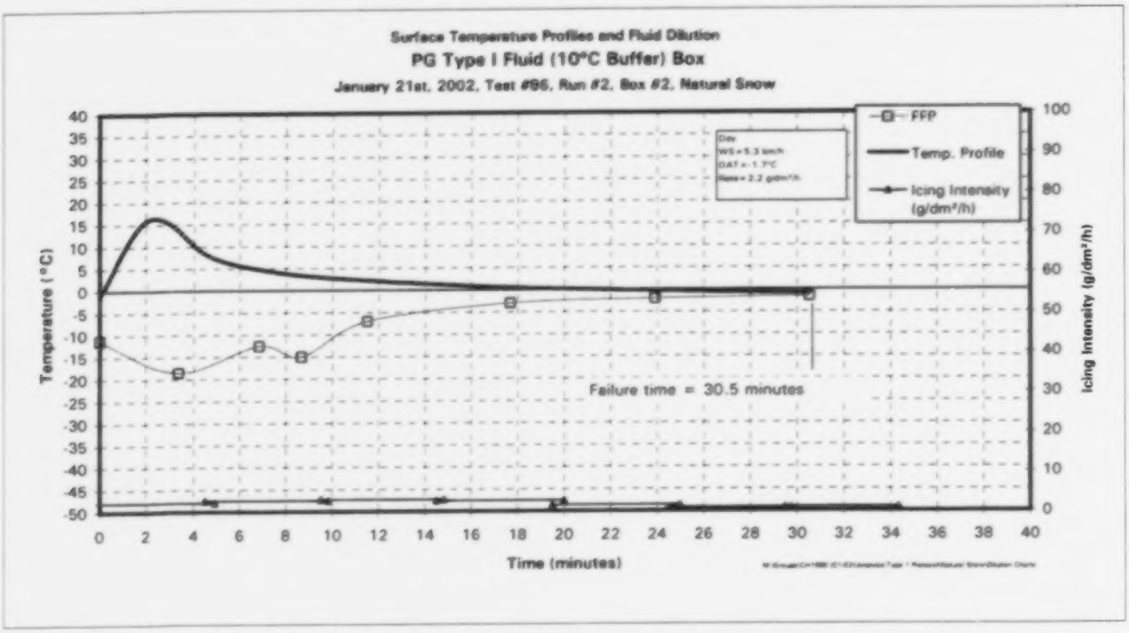
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
January 21st, 2002, Test #80, Run #1, Box #1, Natural Snow



Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
January 21st, 2002, Test #81, Run #1, Box #2, Natural Snow

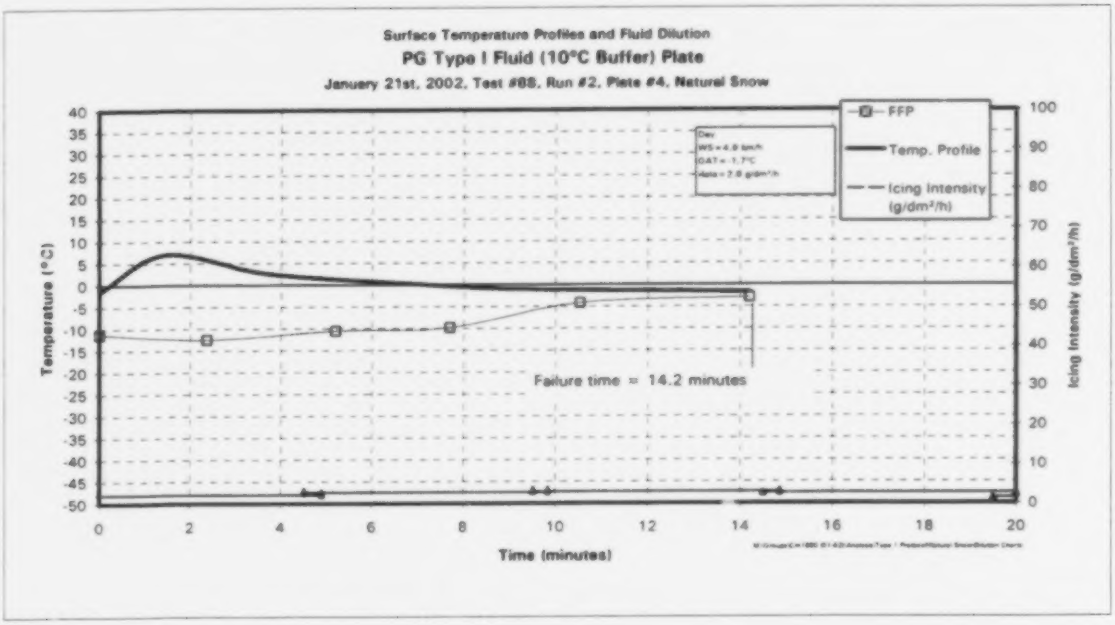

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
January 21st, 2002, Test #82, Run #1, Box #3, Natural Snow


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (Std. Mix) Box
January 21st, 2002, Test #85, Run #2, Box #1, Natural Snow


Surface Temperature Profiles and Fluid Dilution

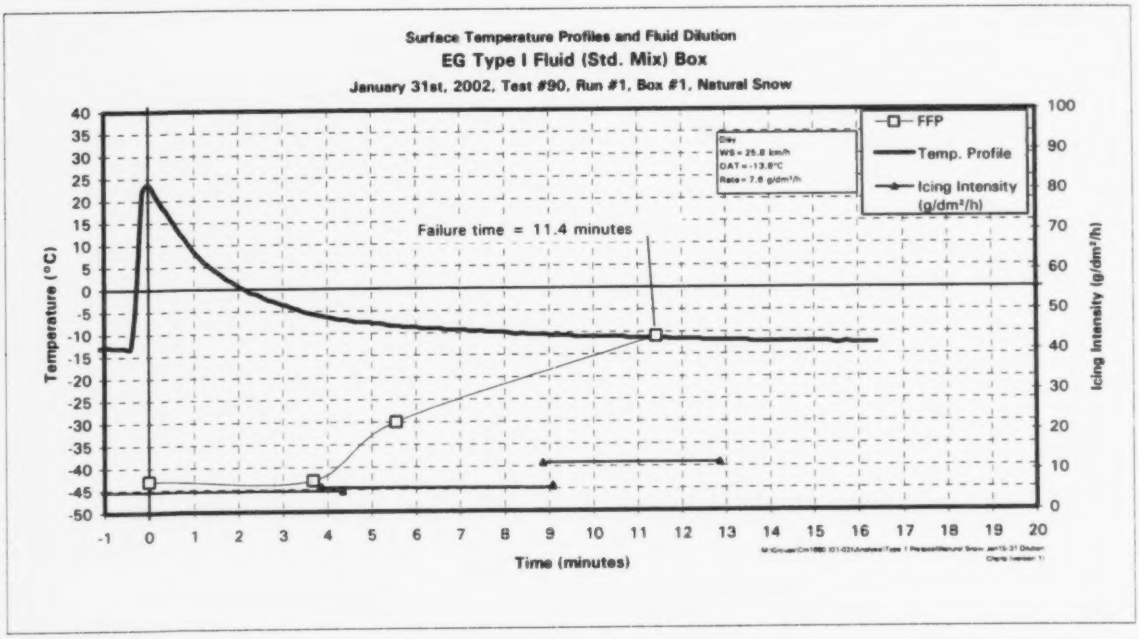
PG Type I Fluid (10°C Buffer) Box

January 21st, 2002, Test #86, Run #2, Box #2, Natural Snow


Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

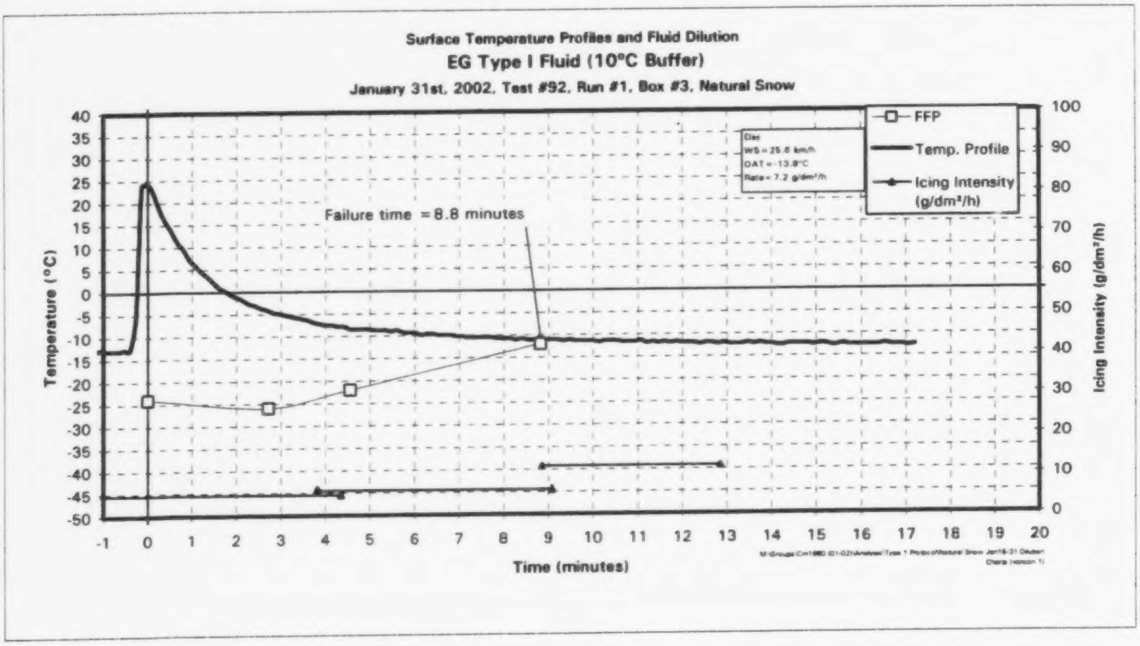
January 21st, 2002, Test #88, Run #2, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

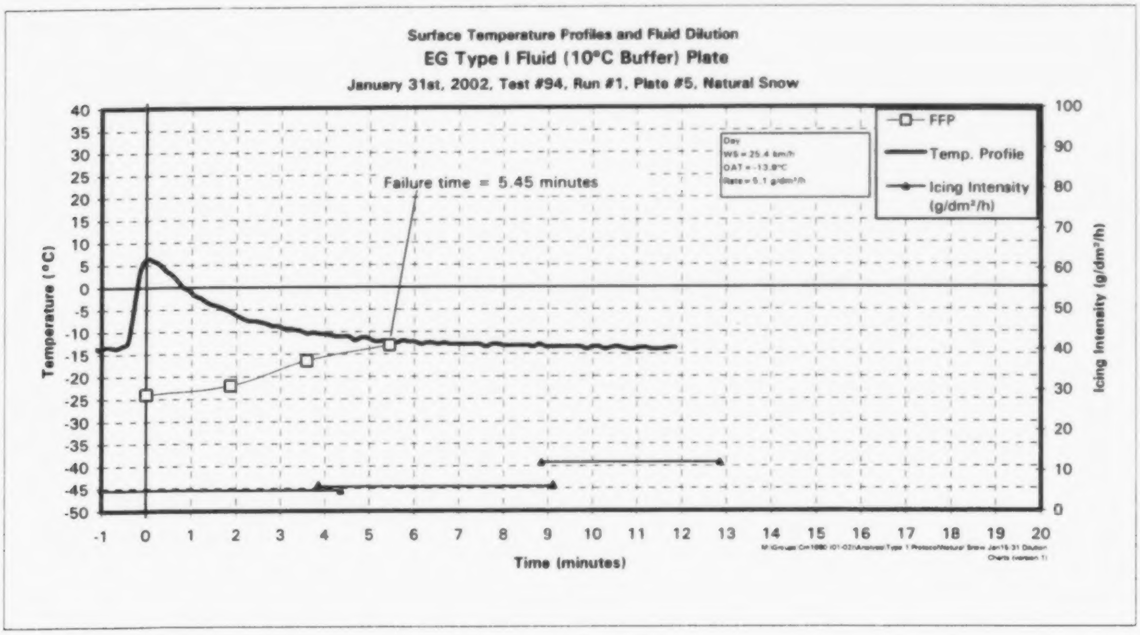
January 31st, 2002, Test #90, Run #1, Box #1, Natural Snow



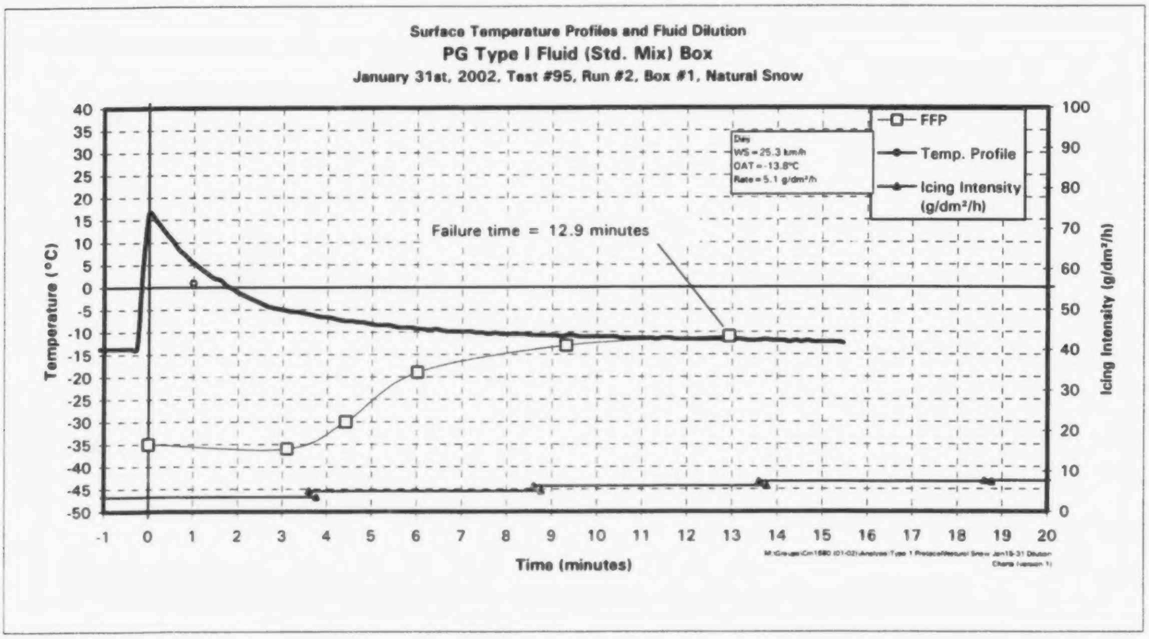
Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer)

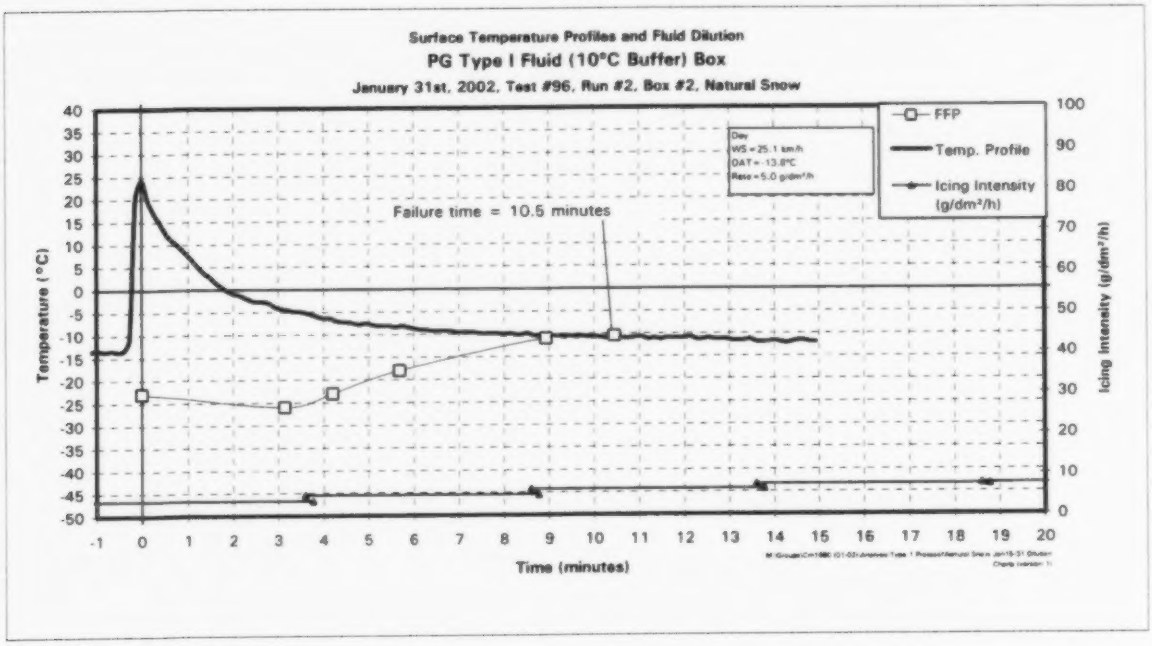
January 31st, 2002, Test #92, Run #1, Box #3, Natural Snow

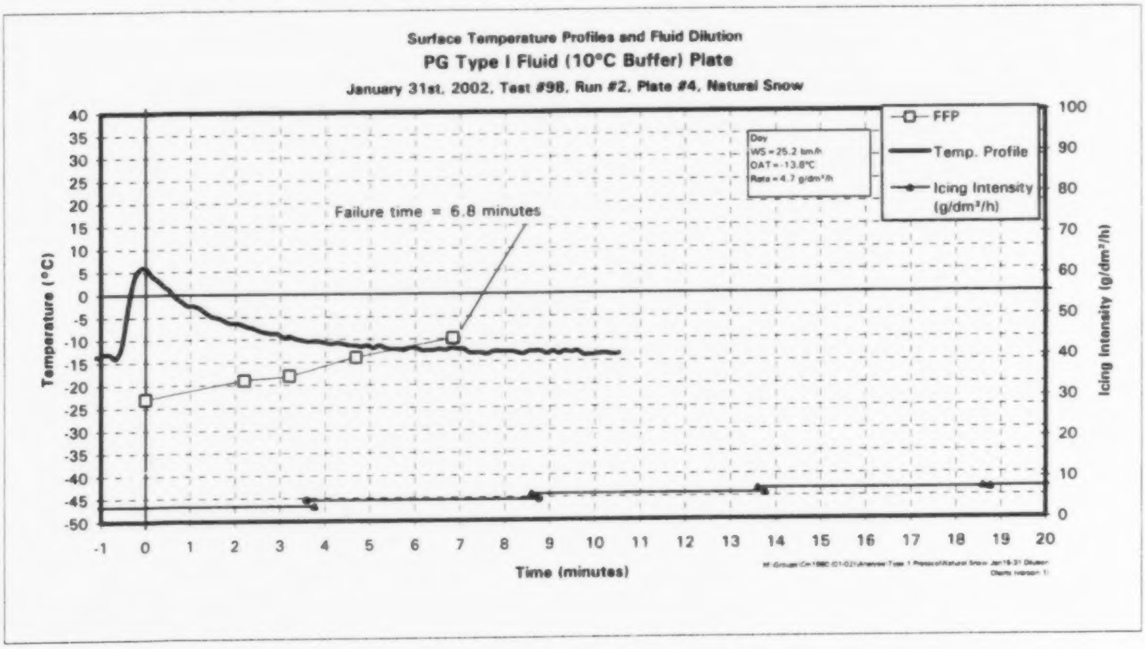


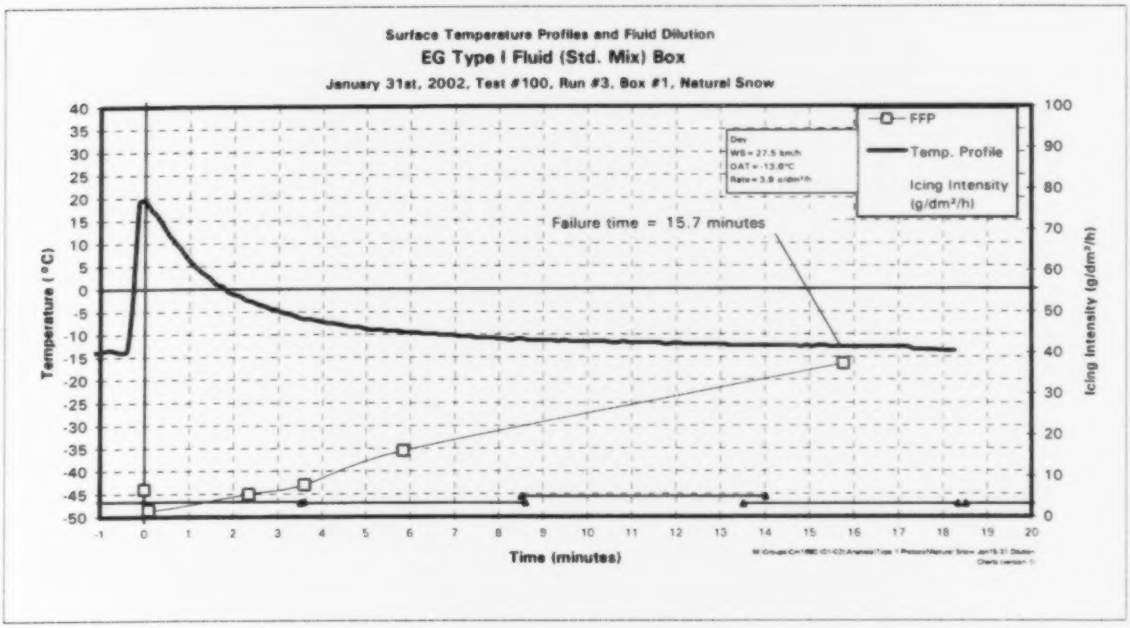
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
January 31st, 2002, Test #94, Run #1, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (Std. Mix) Box
January 31st, 2002, Test #95, Run #2, Box #1, Natural Snow


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
January 31st, 2002, Test #96, Run #2, Box #2, Natural Snow
Day
WS = 25.1 km/h
OAT = -13.8°C
Rate = 5.0 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 10.5 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time (minutes)

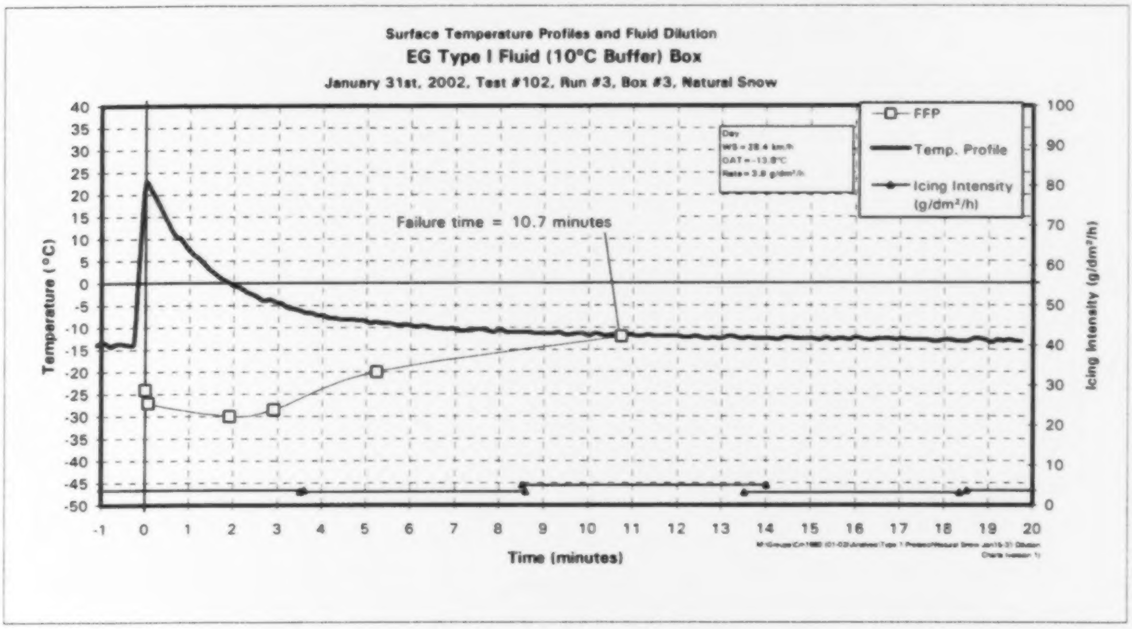

Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
January 31st, 2002, Test #98, Run #2, Plate #4, Natural Snow
Day
WS = 25.2 km/h
OAT = -13.8°C
Rate = 4.7 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 6.8 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time (minutes)



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

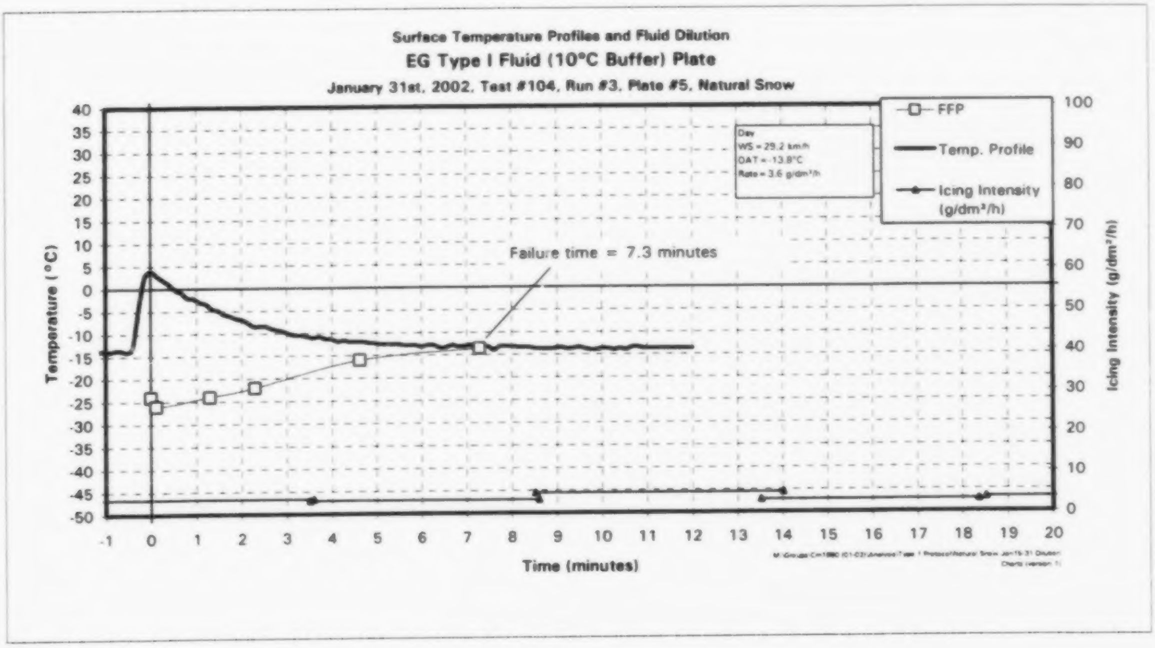
January 31st, 2002, Test #100, Run #3, Box #1, Natural Snow

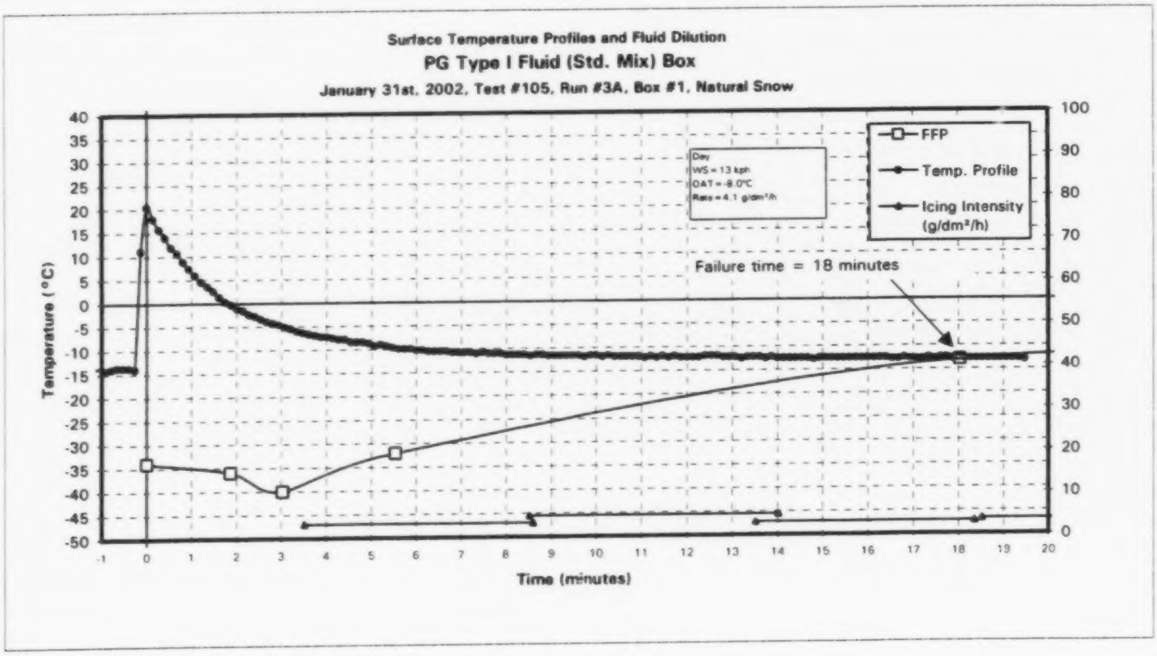


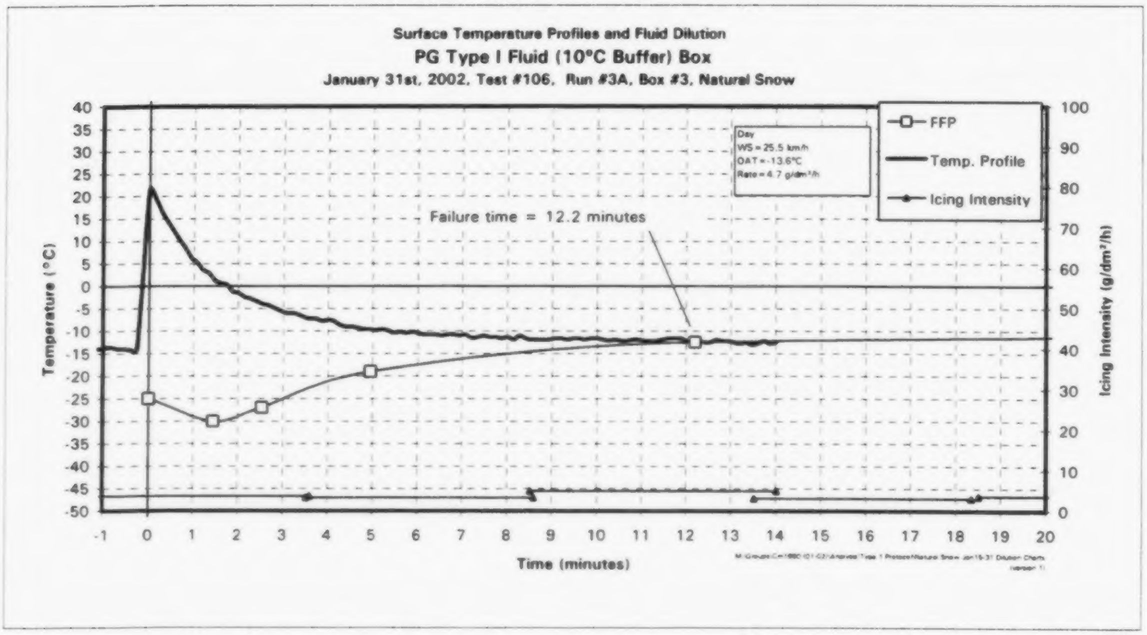
Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

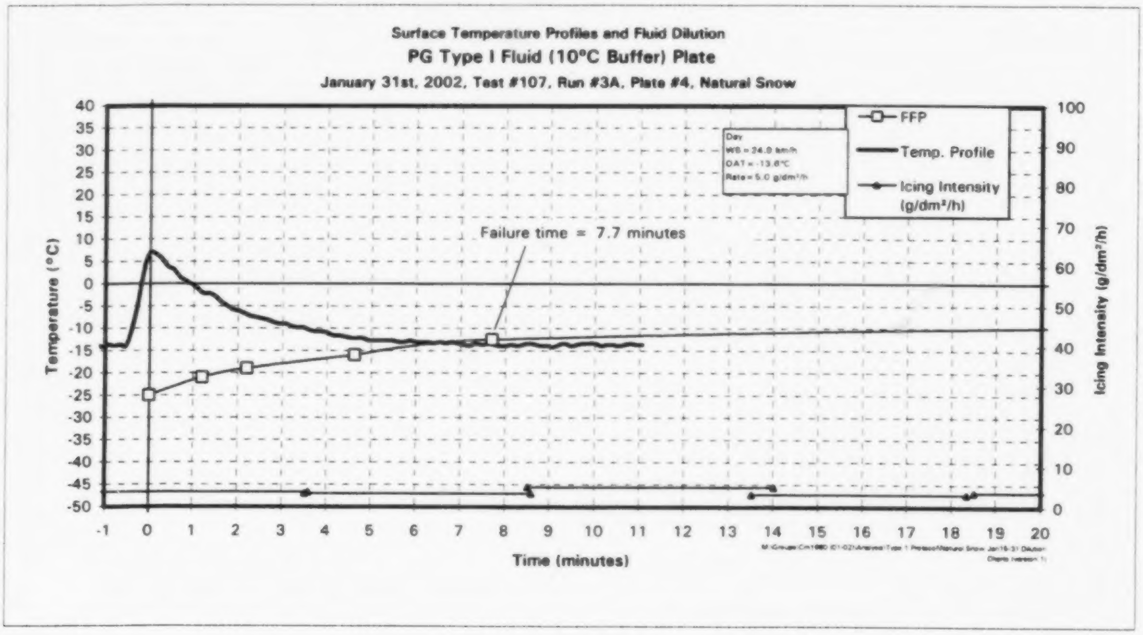
January 31st, 2002, Test #102, Run #3, Box #3, Natural Snow


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
January 31st, 2002, Test #104, Run #3, Plate #5, Natural Snow
Day
WS = 29.2 km/h
OAT = -13.8°C
Rate = 3.6 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 7.3 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Time (minutes)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

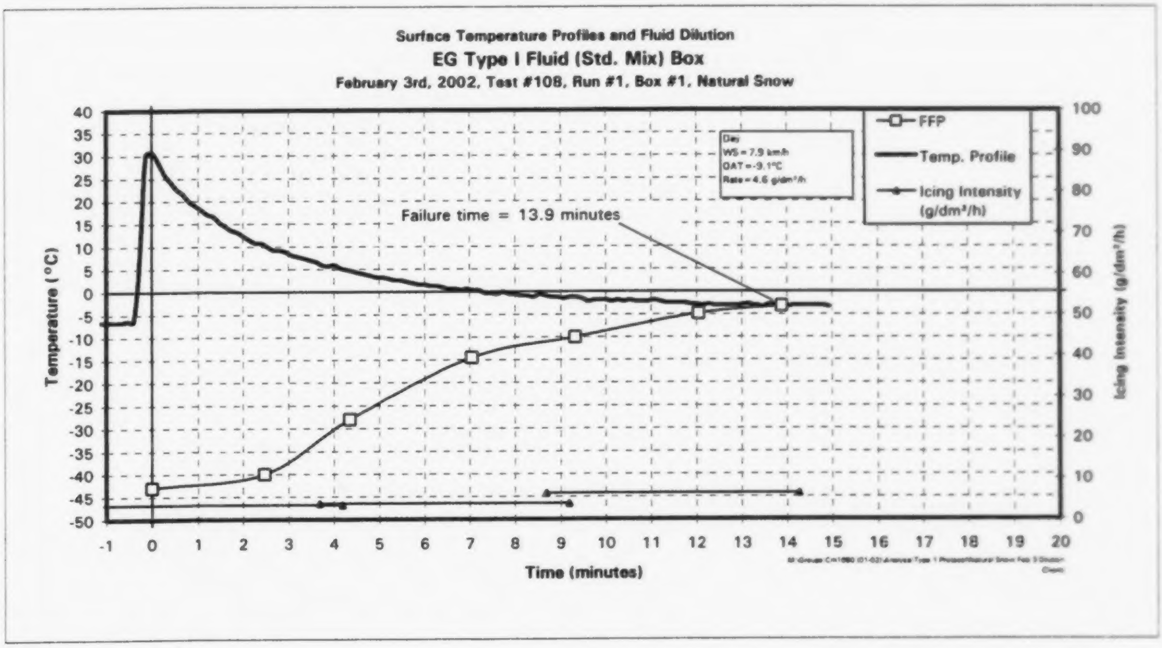

Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (Std. Mix) Box
January 31st, 2002, Test #105, Run #3A, Box #1, Natural Snow
Day
WS = 13 kph
OAT = -8.0°C
Rate = 4.1 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 18 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
100
90
80
70
60
50
40
30
20
10
0
Time (minutes)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
January 31st, 2002, Test #106, Run #3A, Box #3, Natural Snow



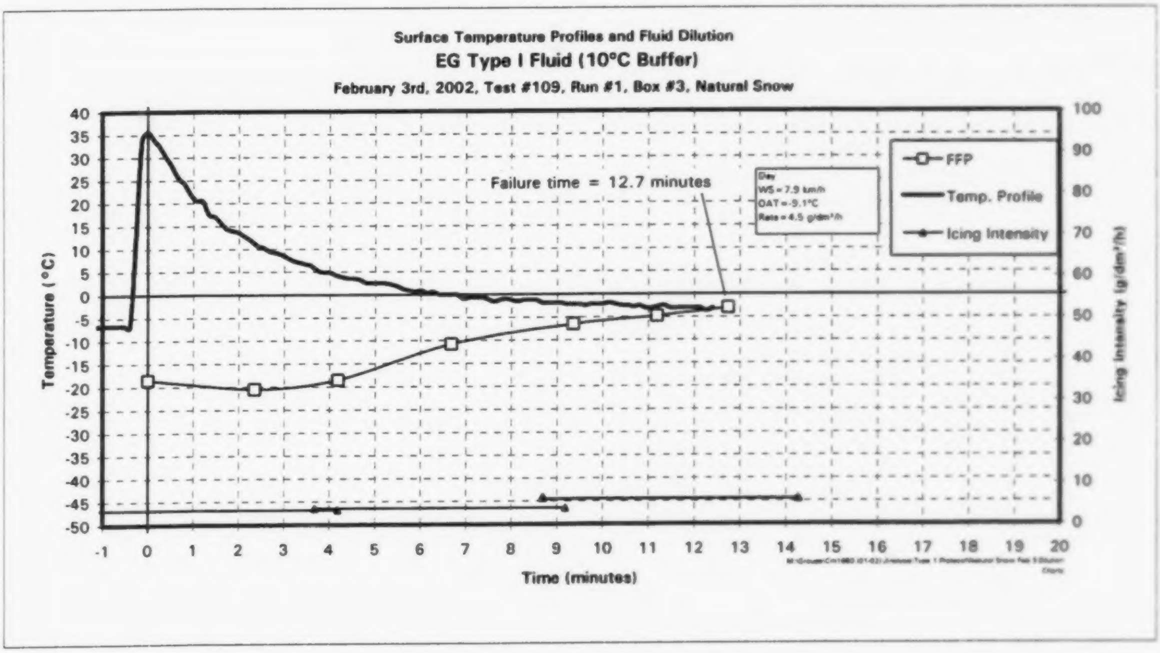
Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
January 31st, 2002, Test #107, Run #3A, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

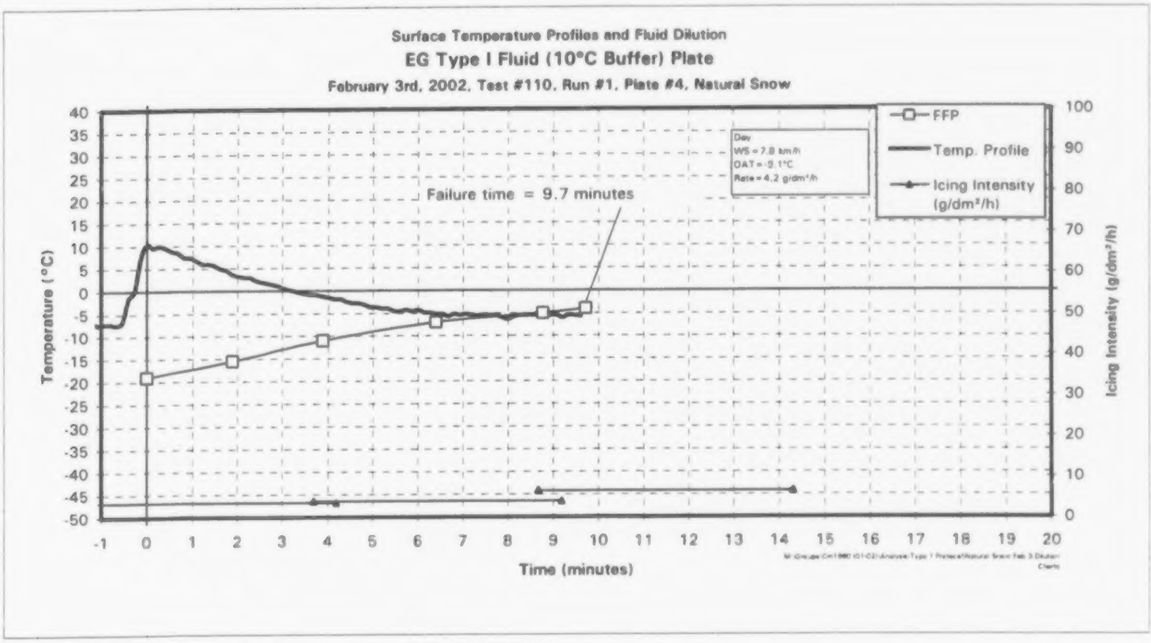
February 3rd, 2002, Test #108, Run #1, Box #1, Natural Snow

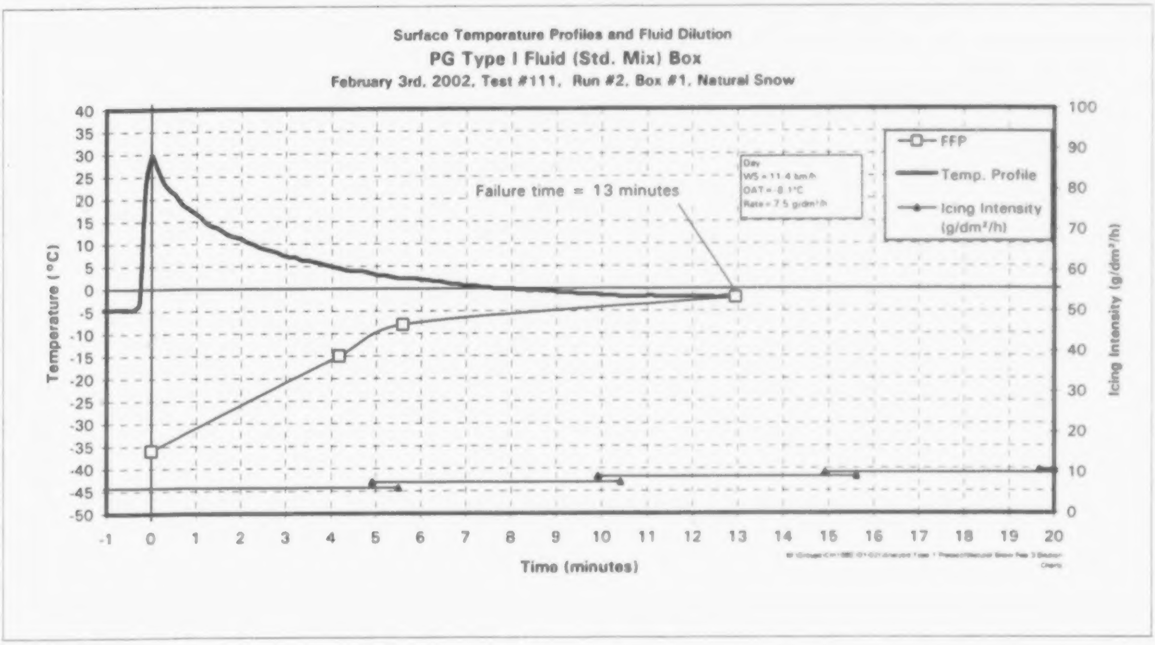


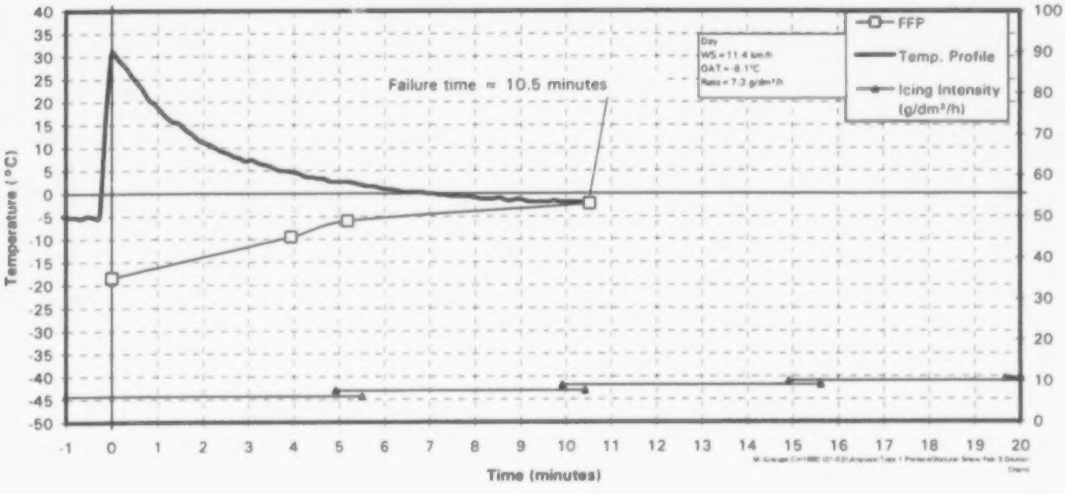
Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer)

February 3rd, 2002, Test #109, Run #1, Box #3, Natural Snow


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
February 3rd, 2002, Test #110, Run #1, Plate #4, Natural Snow

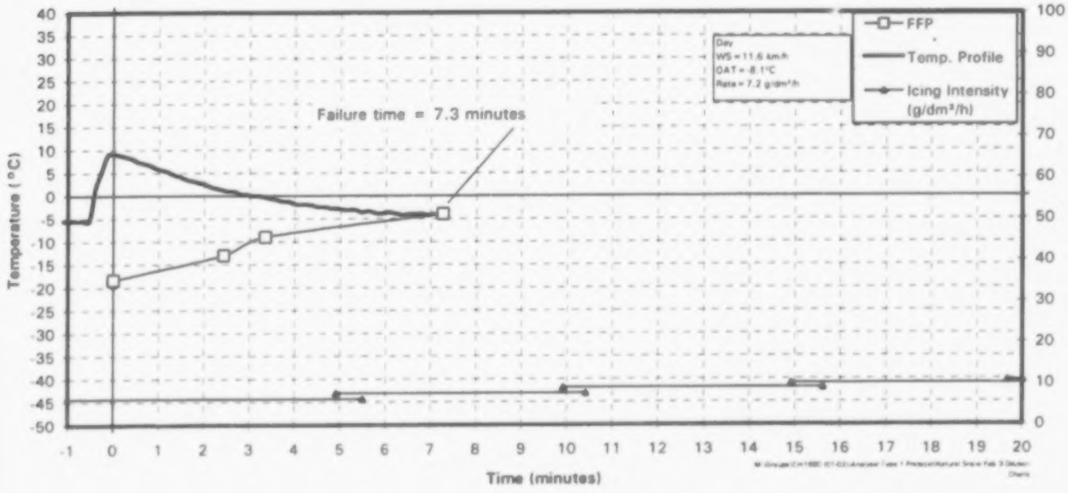

Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (Std. Mix) Box
February 3rd, 2002, Test #111, Run #2, Box #1, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

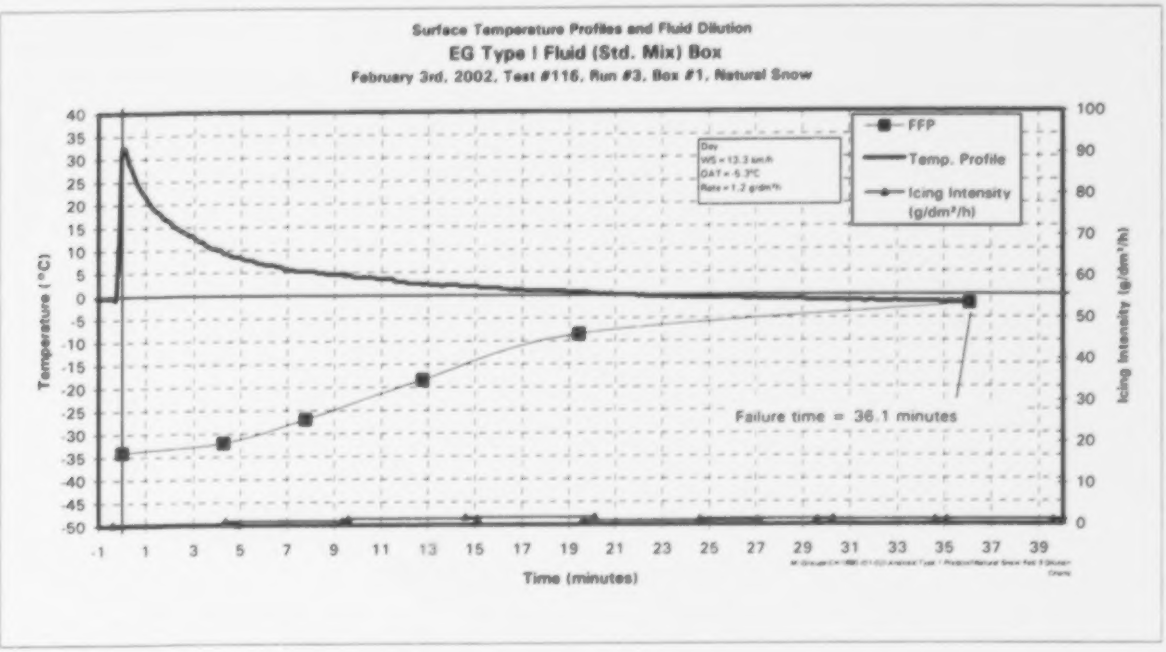
February 3rd, 2002, Test #112, Run #2, Box #2, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

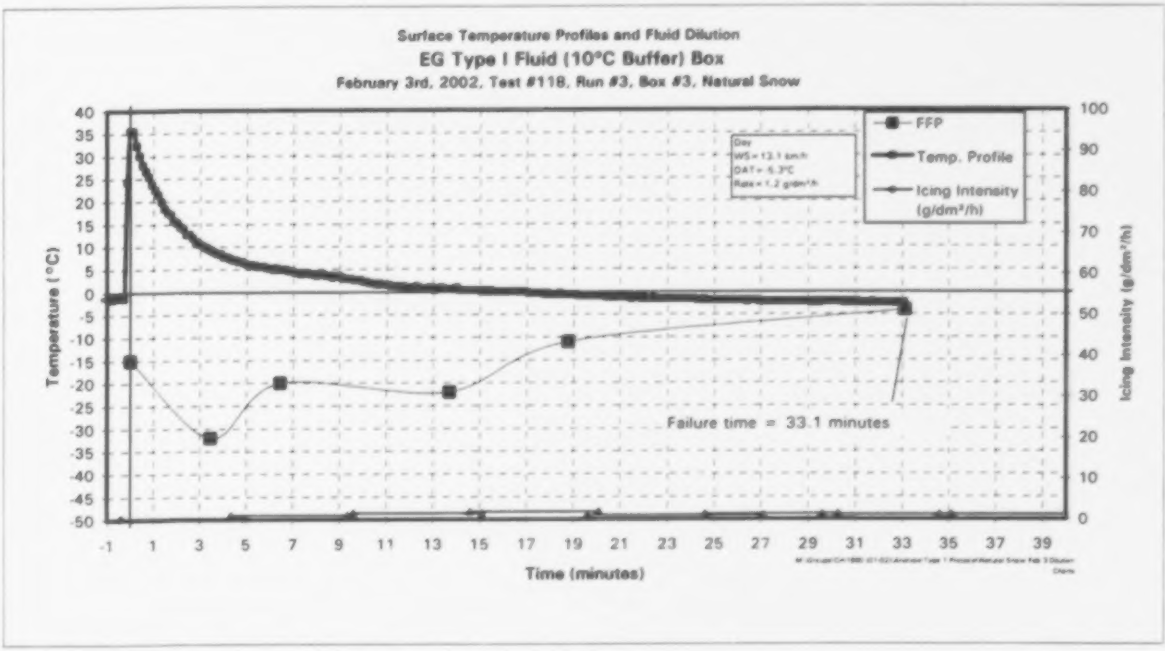
February 3rd, 2002, Test #114, Run #2, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

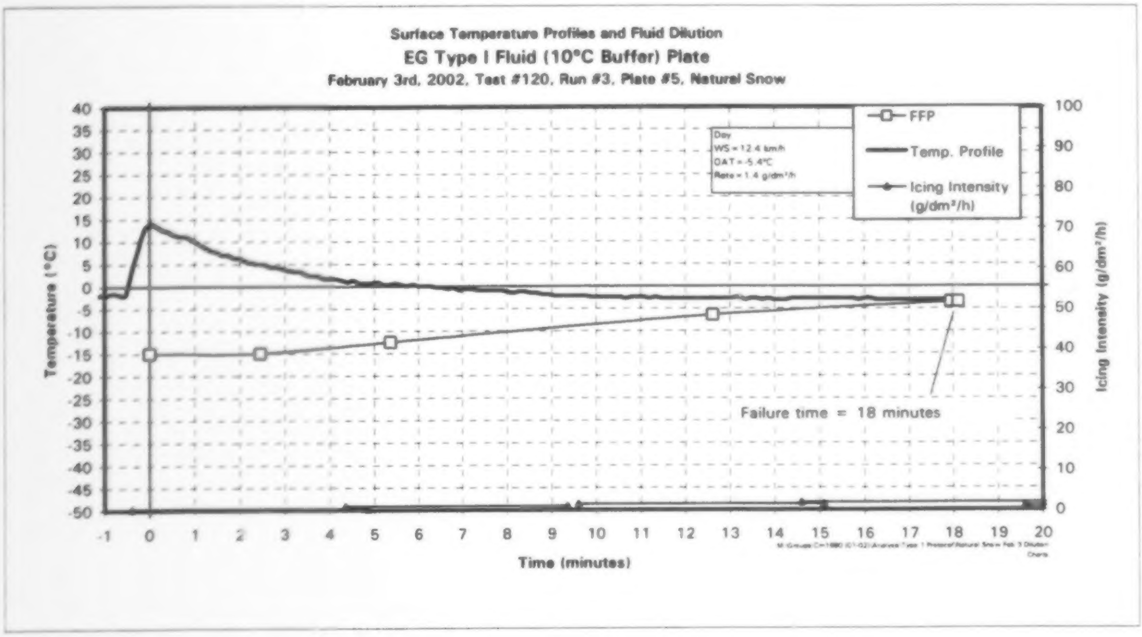
February 3rd, 2002, Test #116, Run #3, Box #1, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

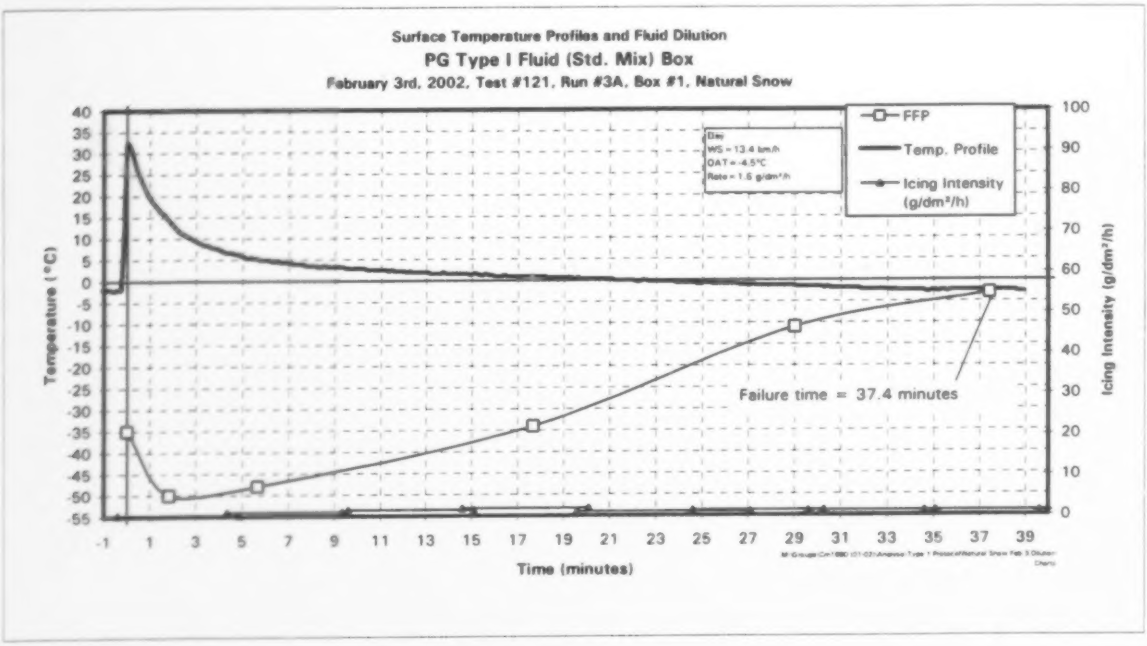
February 3rd, 2002, Test #118, Run #3, Box #3, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

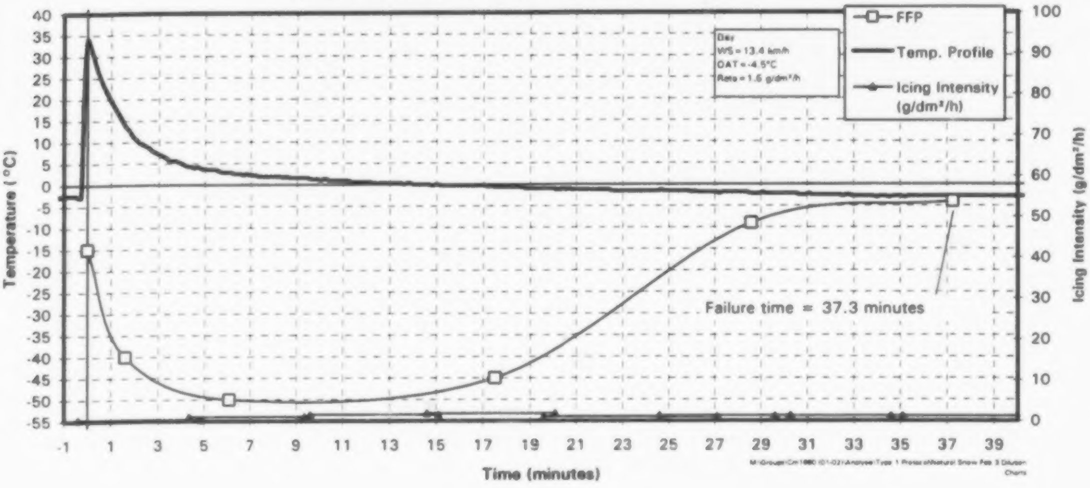
February 3rd, 2002, Test #120, Run #3, Plate #5, Natural Snow



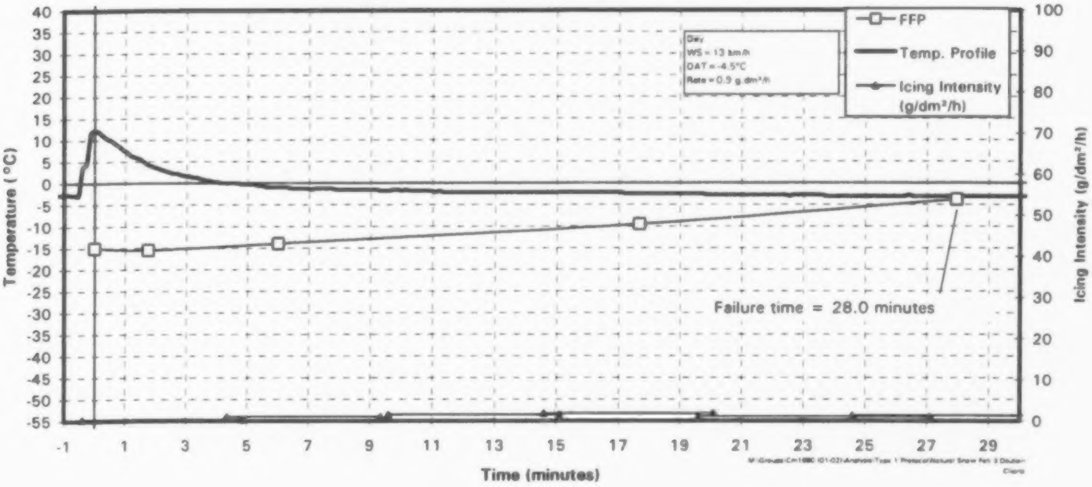
Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (Std. Mix) Box

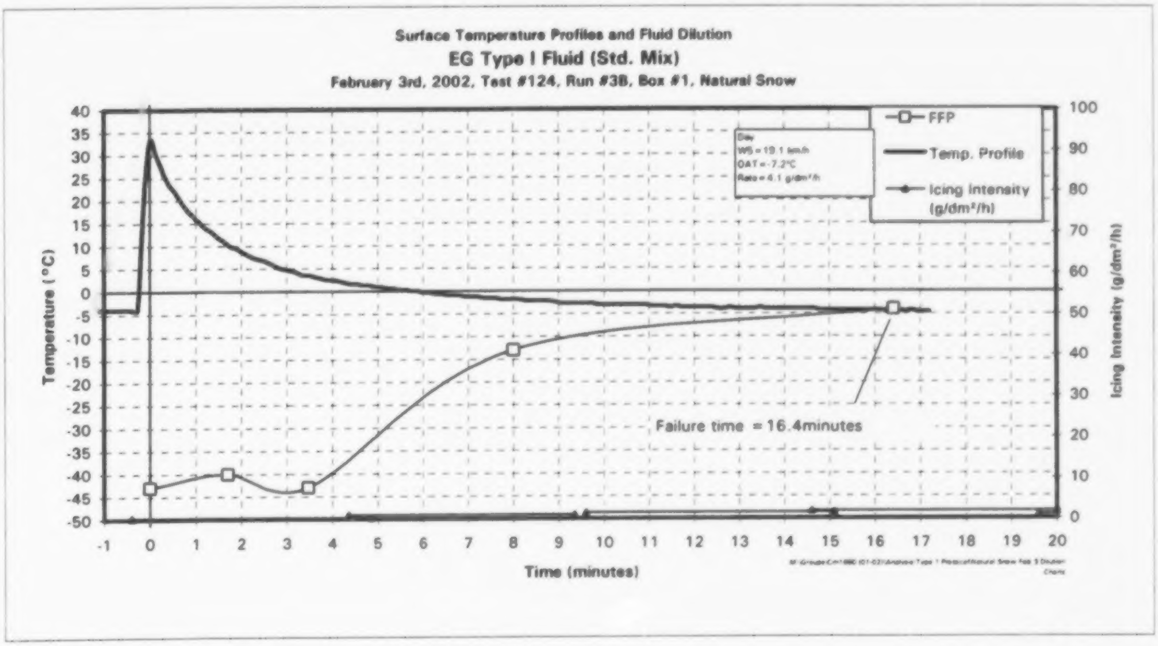
February 3rd, 2002, Test #121, Run #3A, Box #1, Natural Snow



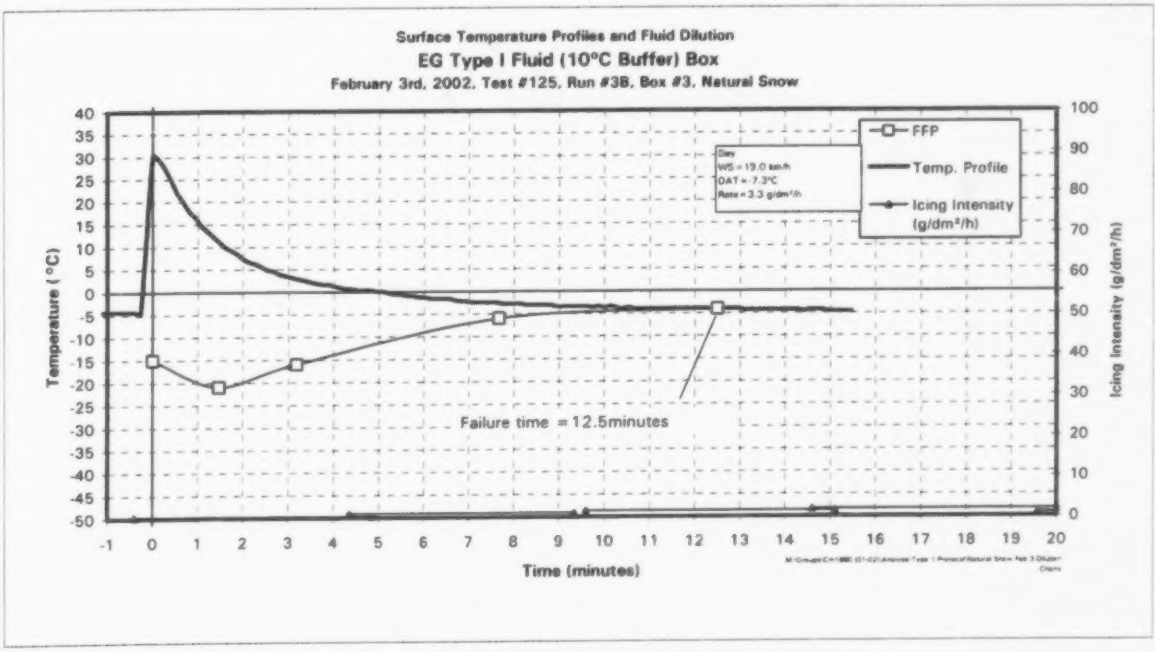
Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
February 3rd, 2002, Test #122, Run #3A, Box #3, Natural Snow



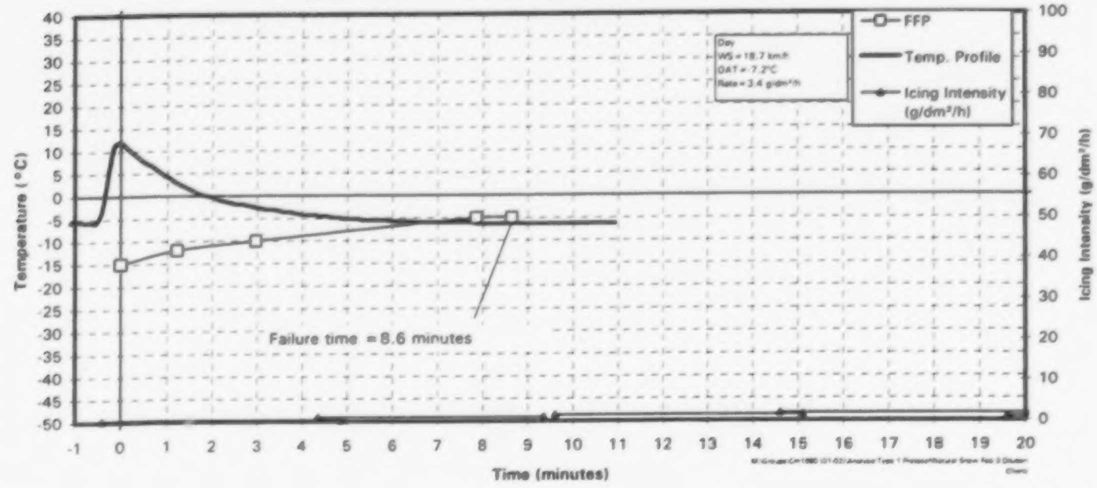
Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
February 3rd, 2002, Test #123, Run #3A, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix)
February 3rd, 2002, Test #124, Run #3B, Box #1, Natural Snow



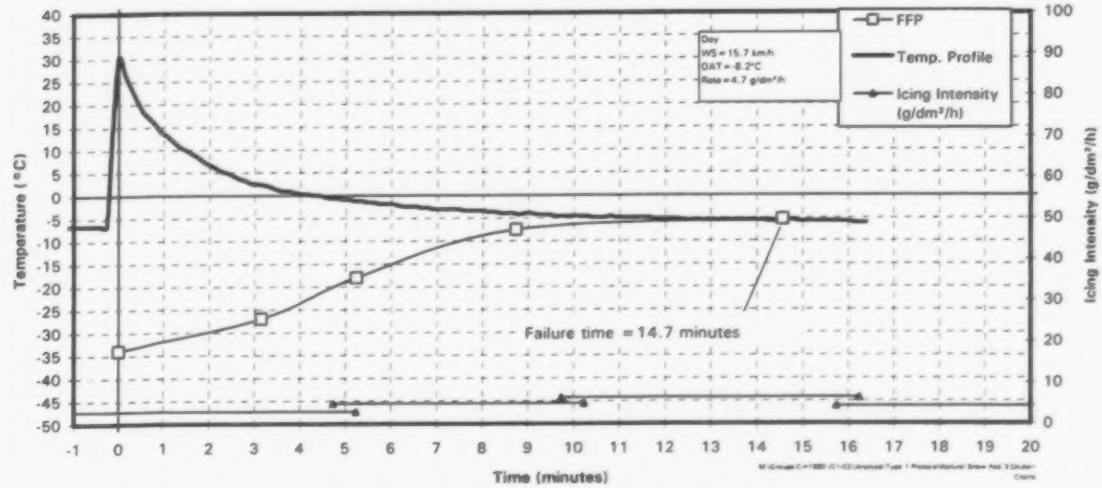
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
February 3rd, 2002, Test #125, Run #3B, Box #3, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

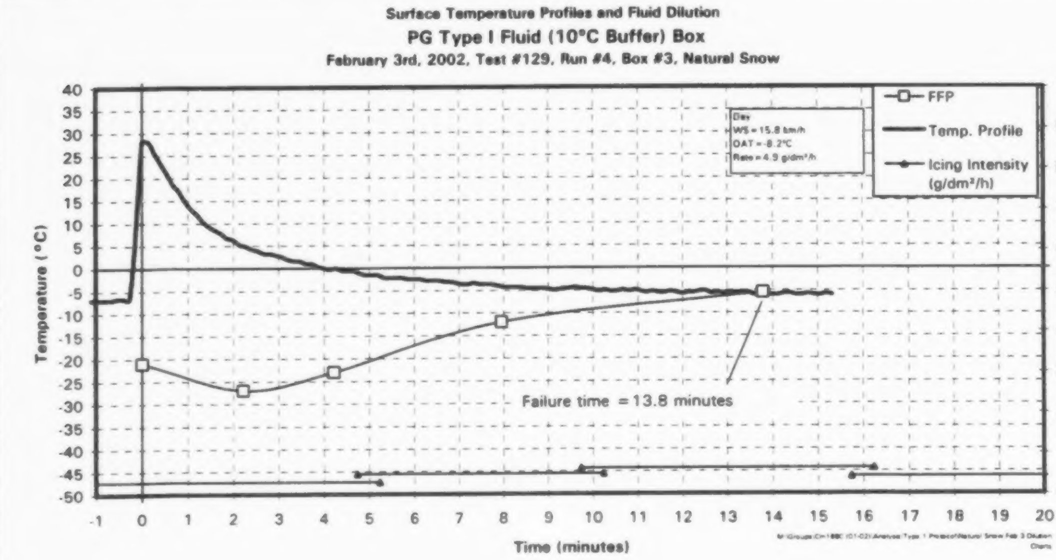
February 3rd, 2002, Test #126, Run #3B, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (Std. Mix) Box

February 3rd, 2002, Test #127, Run #4, Box #1, Natural Snow

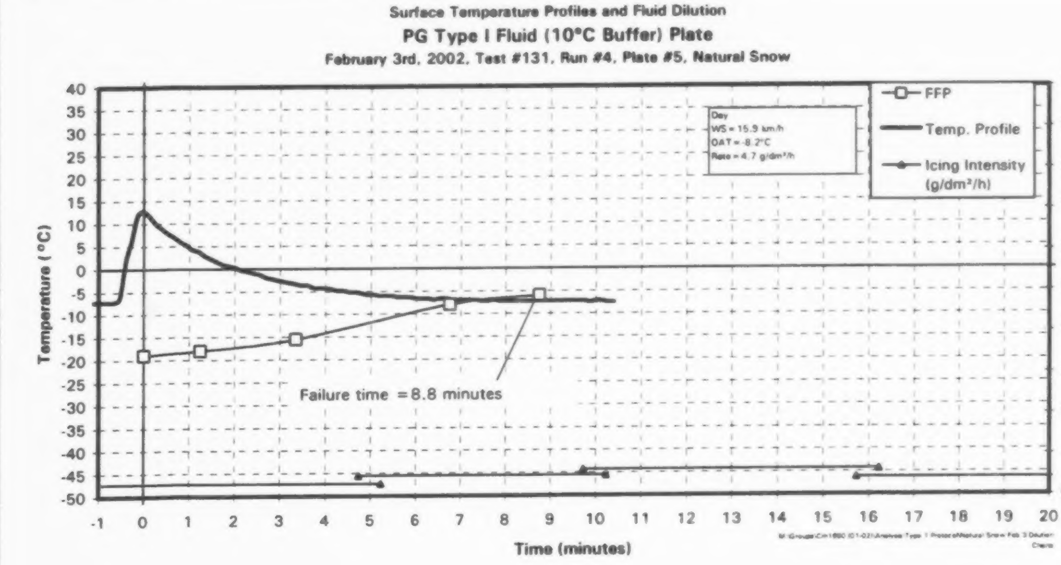


Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

February 3rd, 2002, Test #129, Run #4, Box #3, Natural Snow

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\Natural Snow Feb 3 Dilution Charts



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

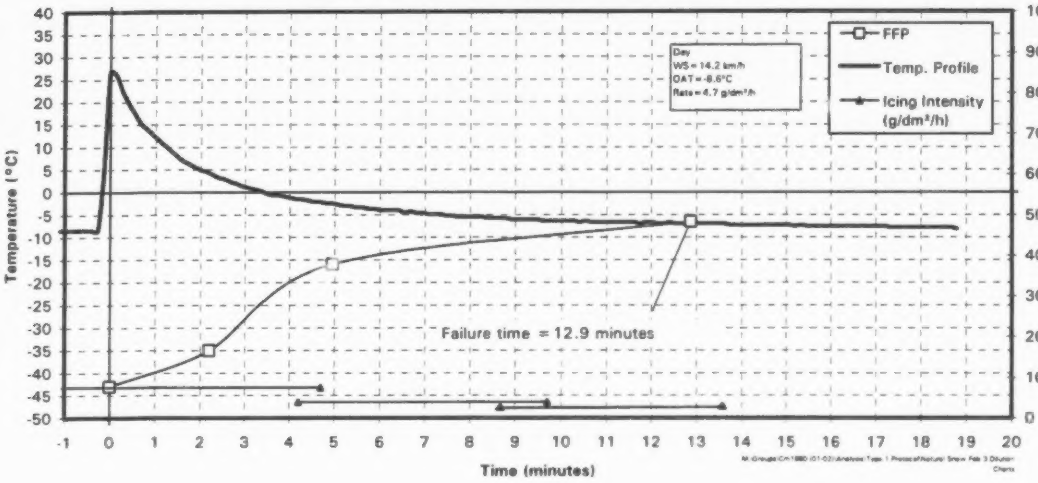
February 3rd, 2002, Test #131, Run #4, Plate #5, Natural Snow

M:\Groups\Cm1680 (01-02)\Analysis\Type 1 Protocol\Natural Snow Feb 3 Dilution Charts

Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

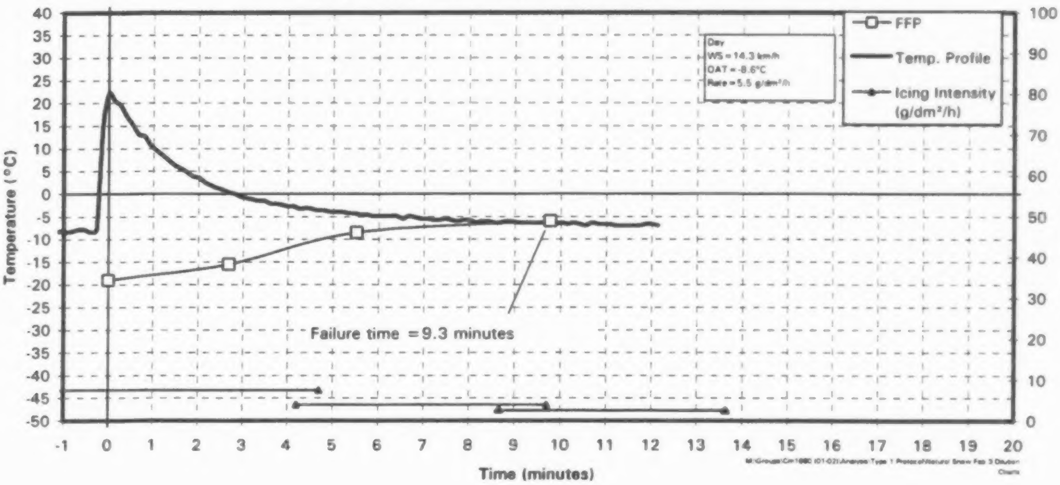
February 3rd, 2002, Test #132, Run #5, Box #1, Natural Snow

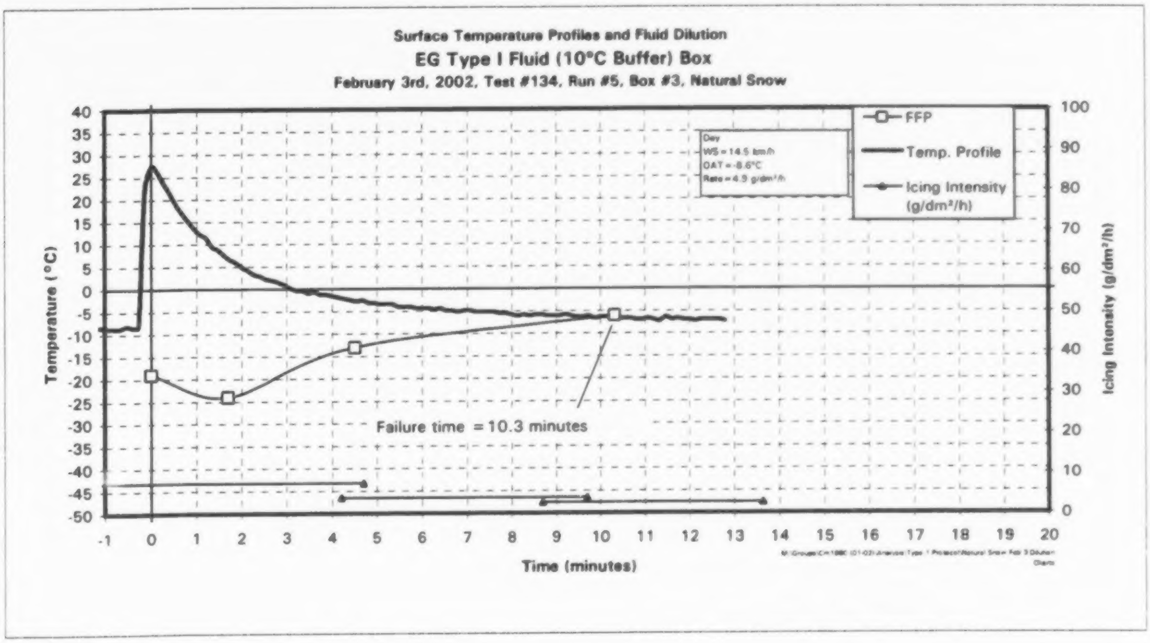


Surface Temperature Profiles and Fluid Dilution

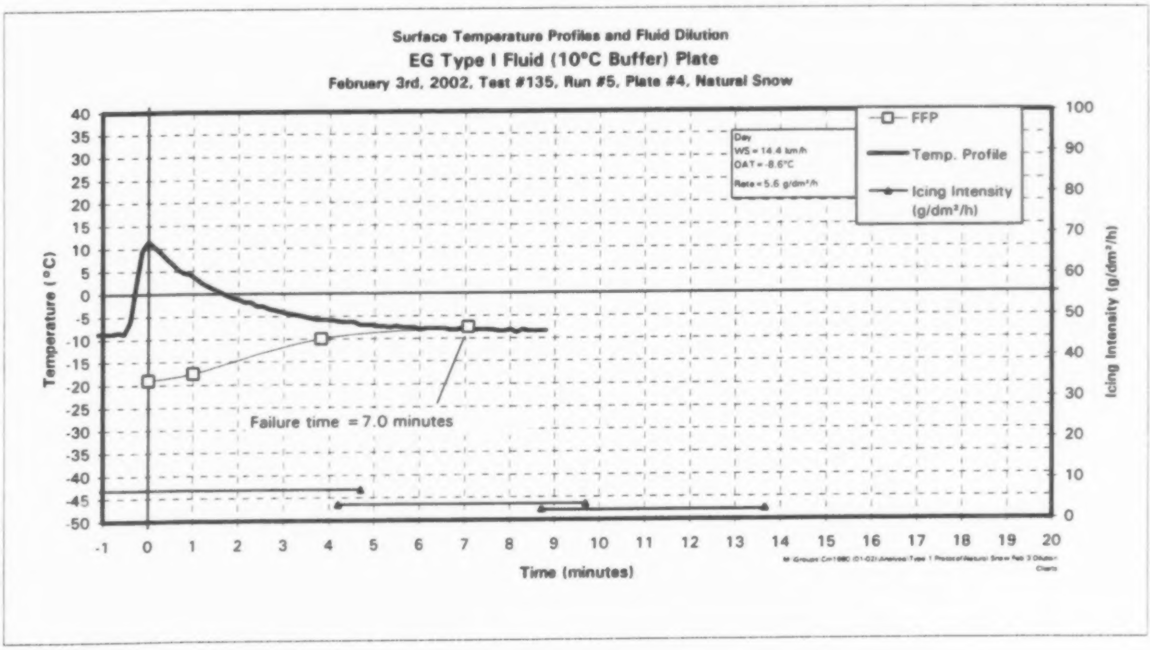
PG Type I Fluid (10°C Buffer) Box

February 3rd, 2002, Test #133, Run #5, Box #2, Natural Snow





Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
February 3rd, 2002, Test #134, Run #5, Box #3, Natural Snow

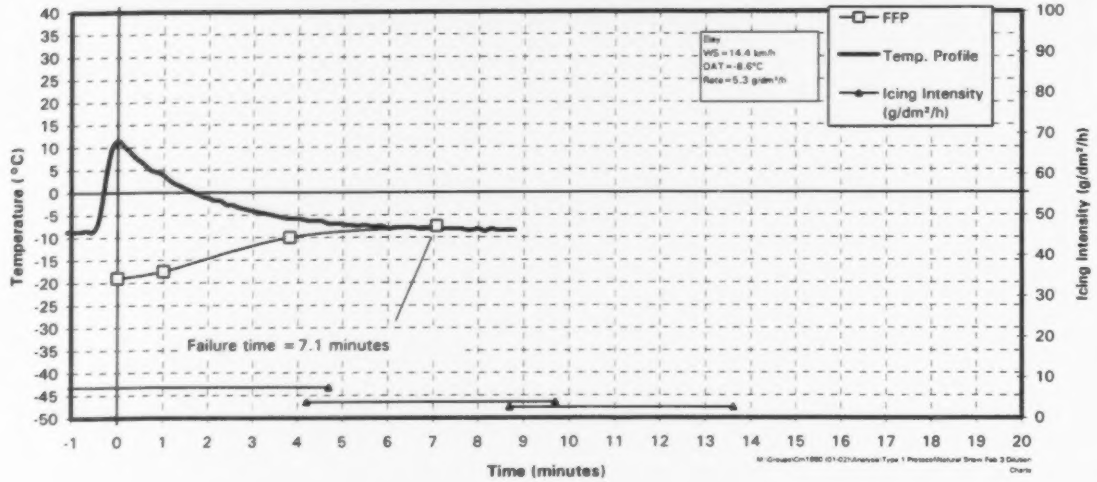


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
February 3rd, 2002, Test #135, Run #5, Plate #4, Natural Snow

Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

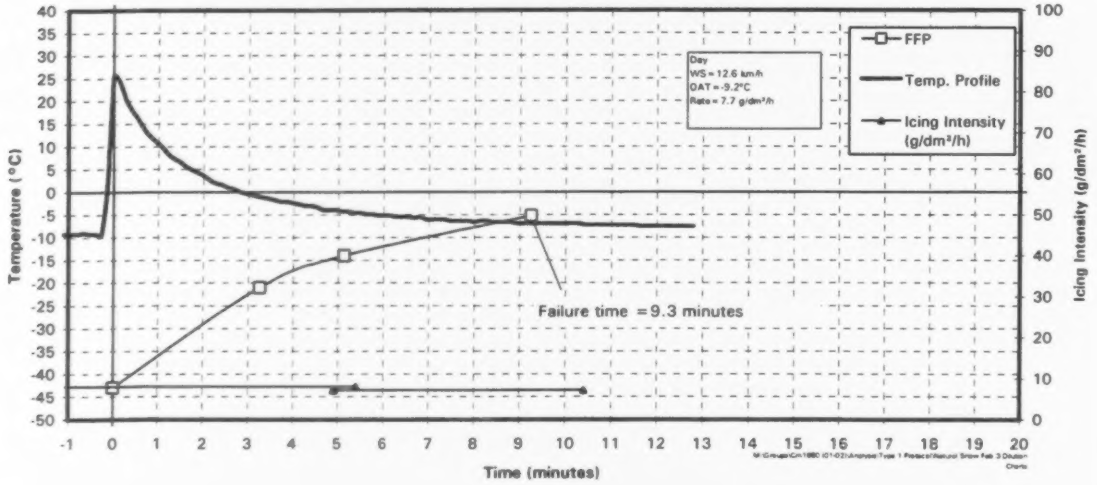
February 3rd, 2002, Test #136, Run #5, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

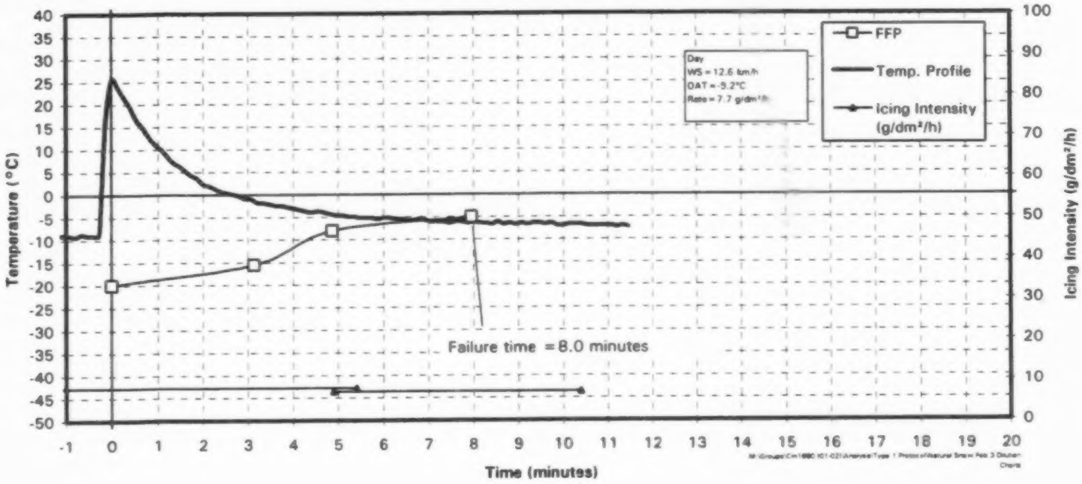
February 3rd, 2002, Test #137, Run #6, Box #1, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

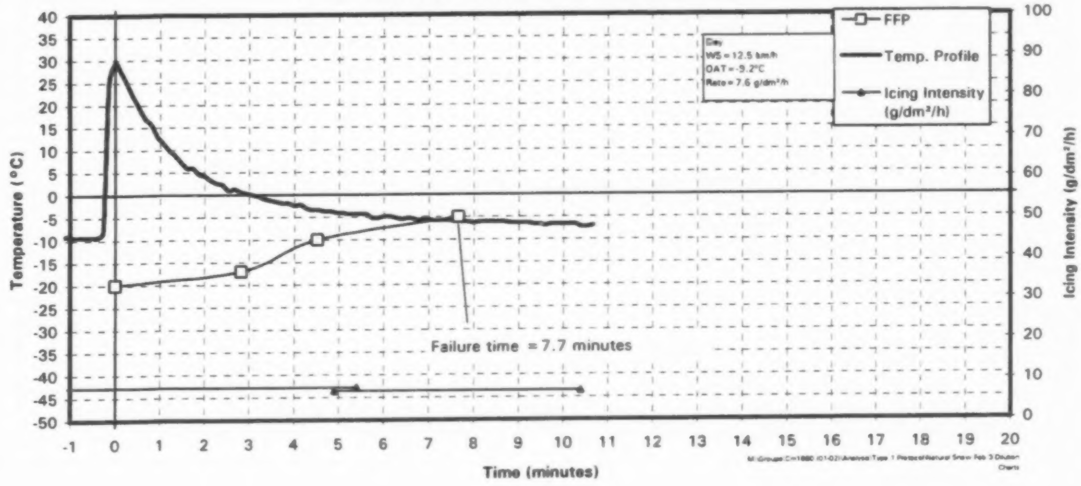
February 3rd, 2002, Test #138, Run #6, Box #2, Natural Snow

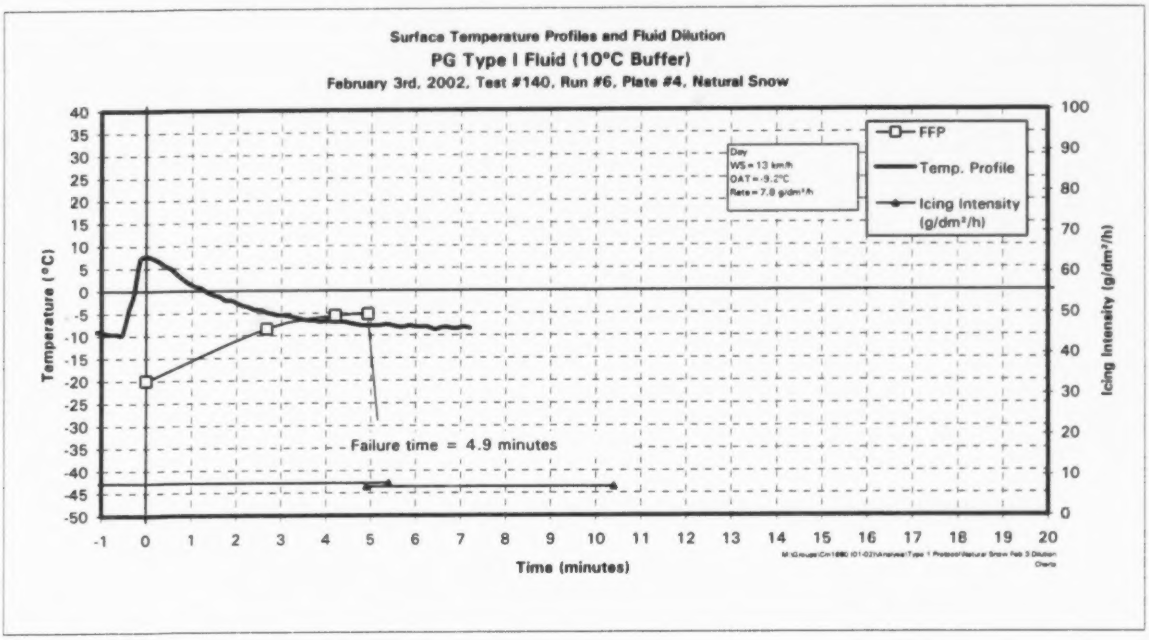


Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

February 3rd, 2002, Test #139, Run #6, Box #3, Natural Snow

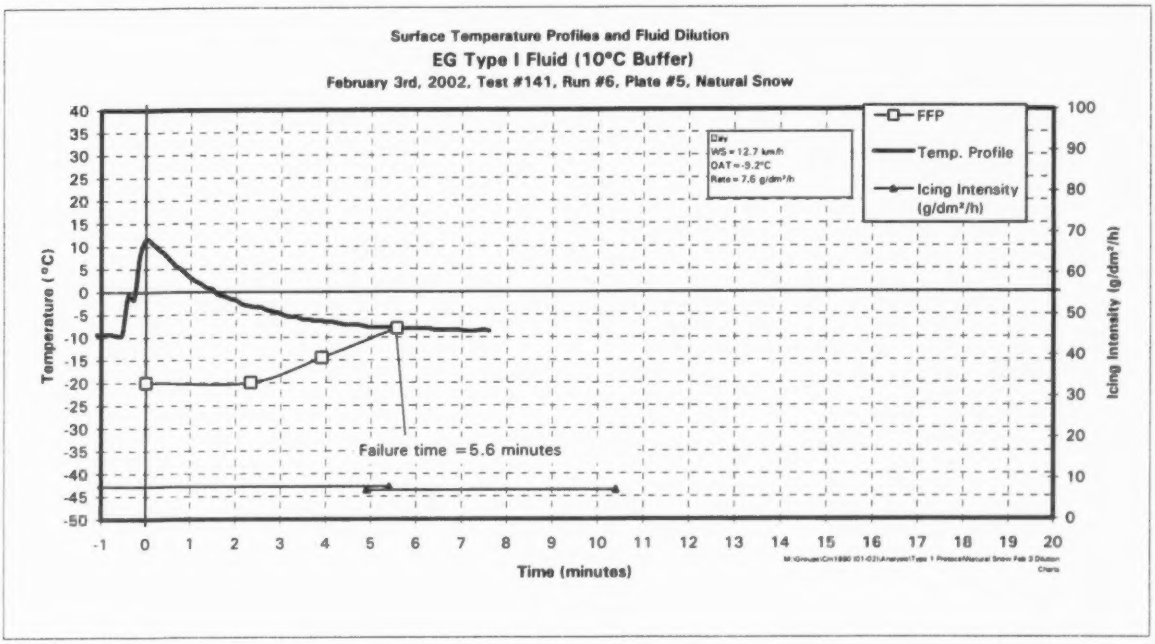




Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer)

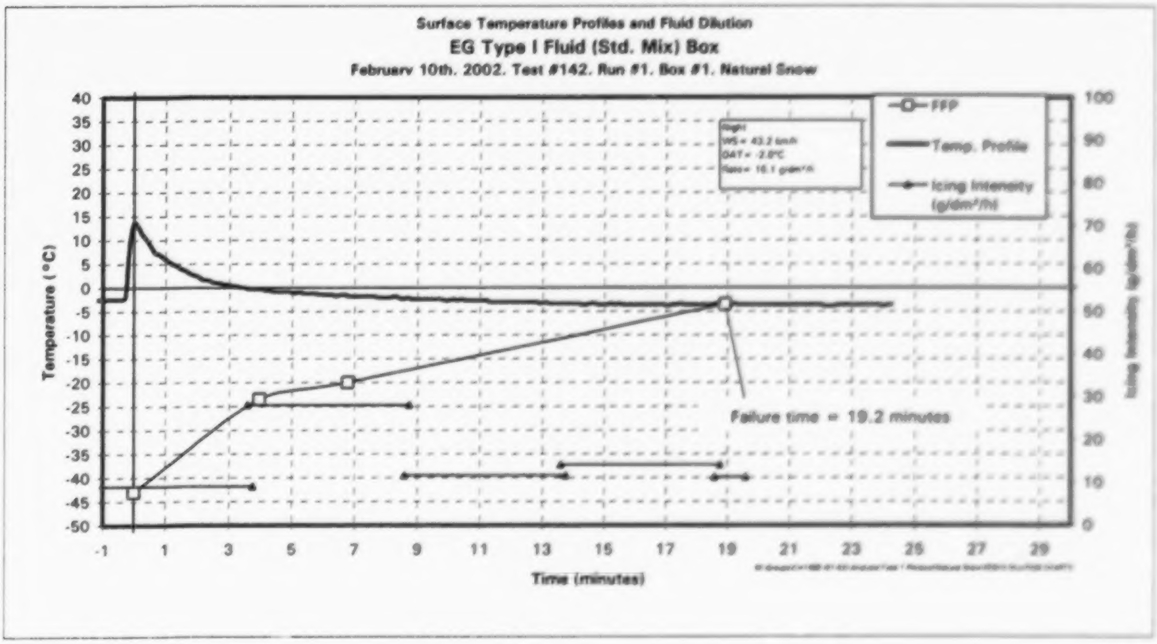
February 3rd, 2002, Test #140, Run #6, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer)

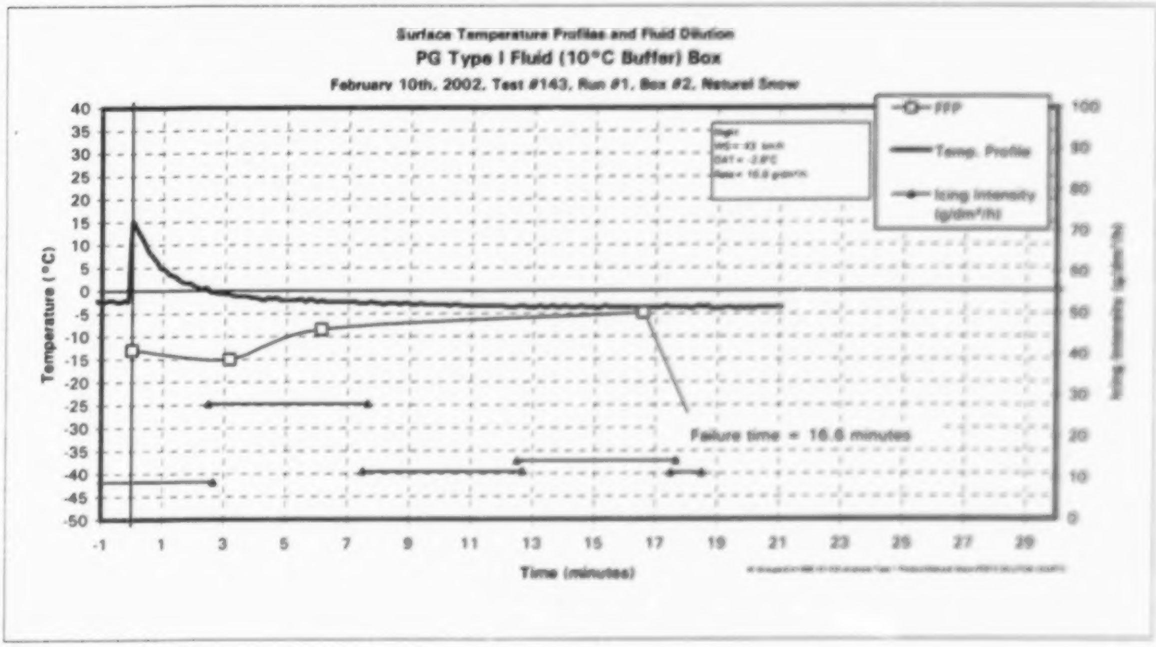
February 3rd, 2002, Test #141, Run #6, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

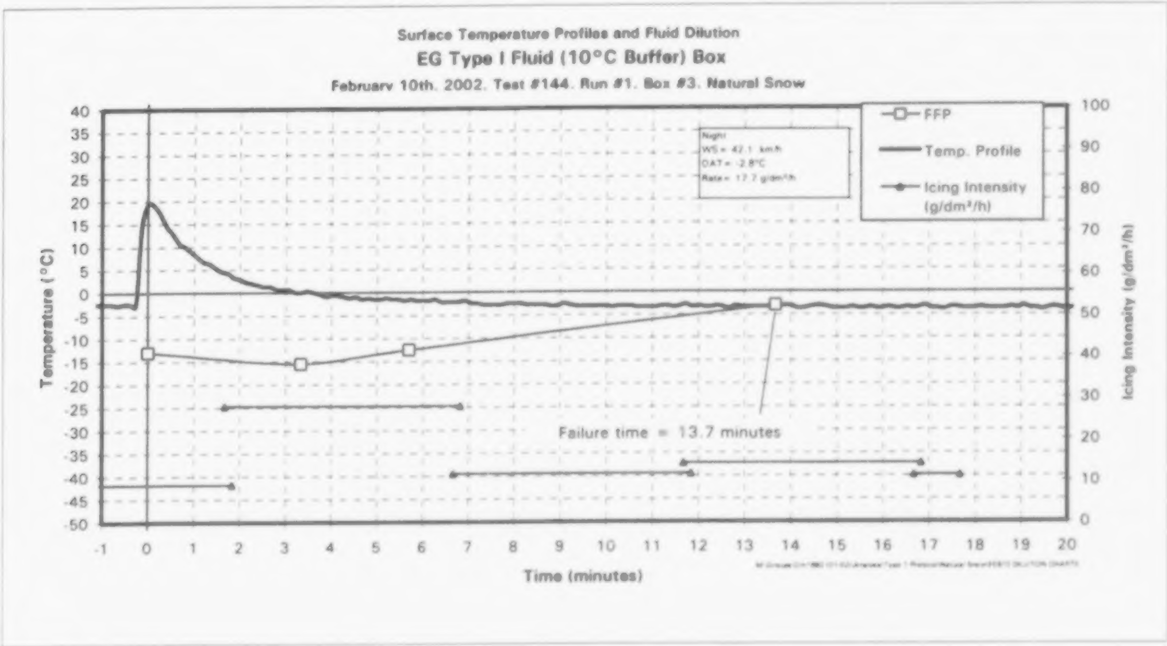
February 10th, 2002, Test #142, Run #1, Box #1, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

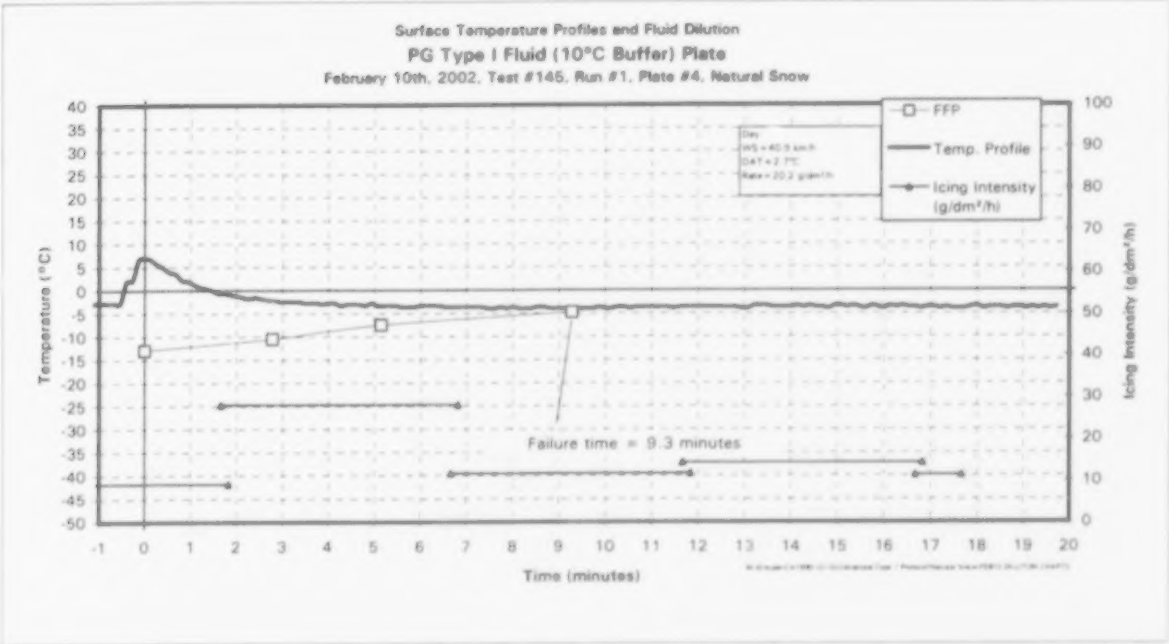
February 10th, 2002, Test #143, Run #1, Box #2, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

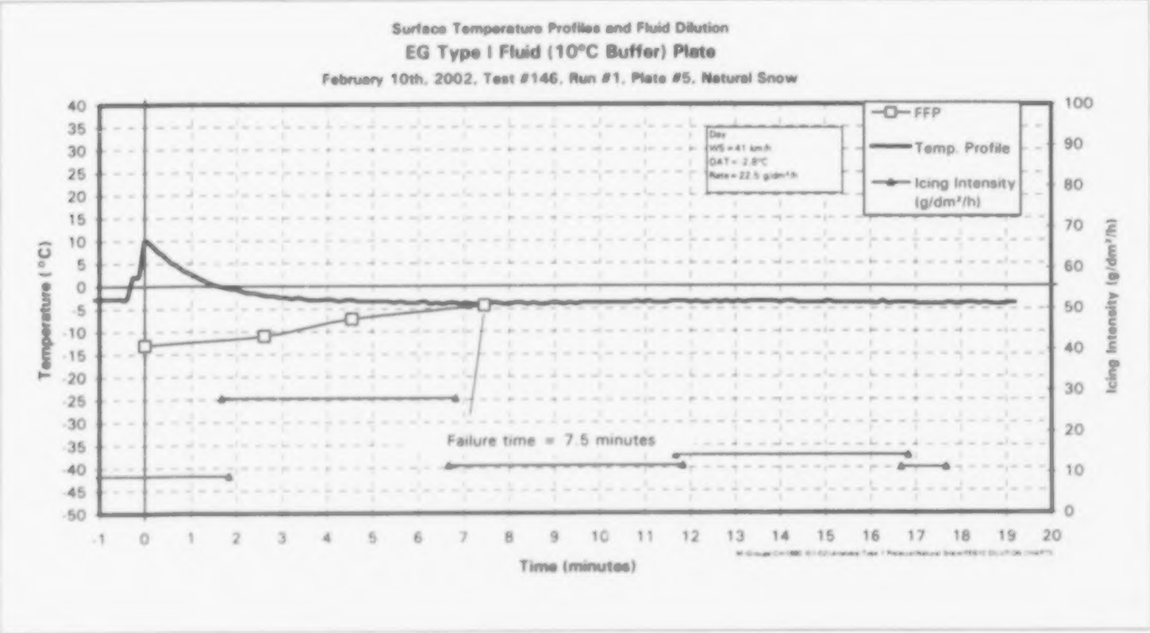
February 10th, 2002, Test #144, Run #1, Box #3, Natural Snow

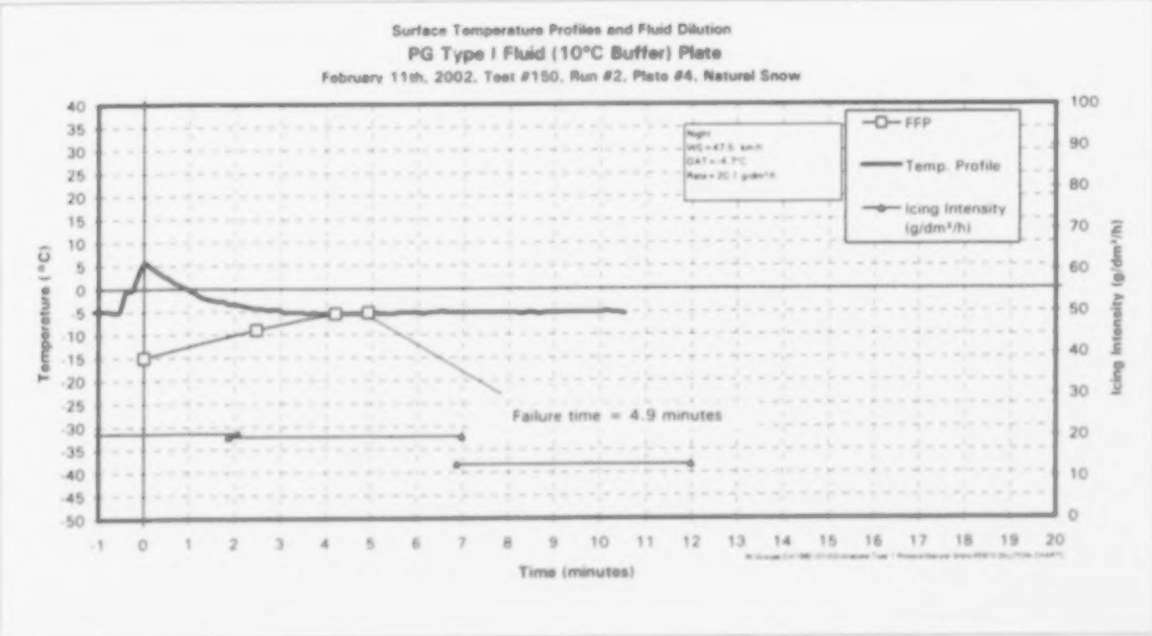


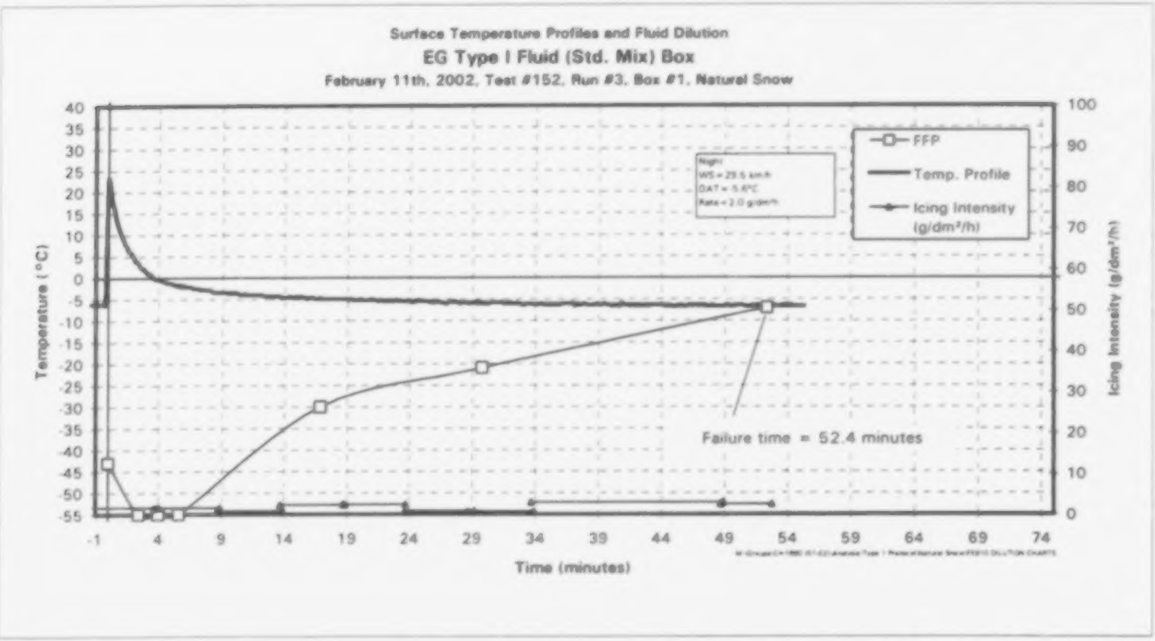
Surface Temperature Profiles and Fluid Dilution

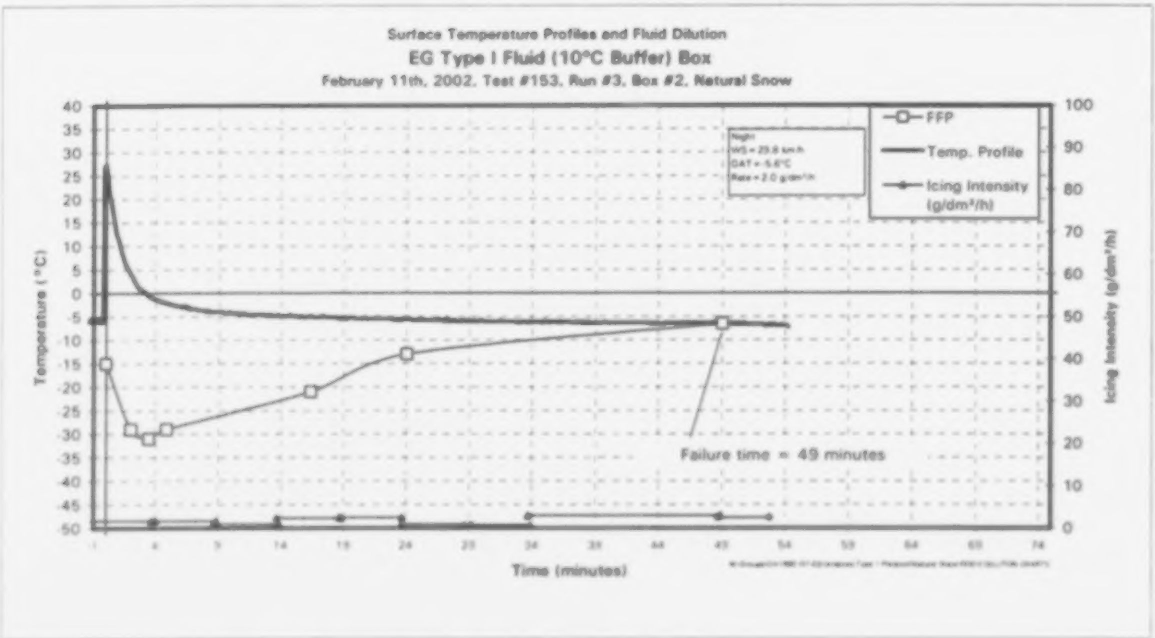
PG Type I Fluid (10°C Buffer) Plate

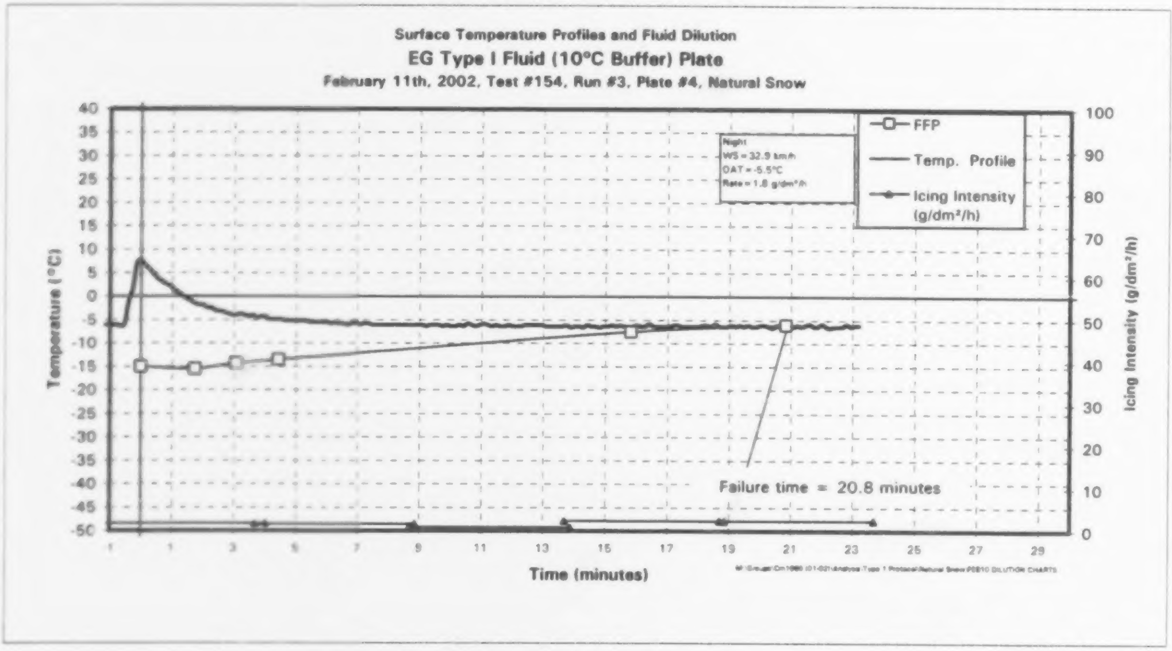
February 10th, 2002, Test #145, Run #1, Plate #4, Natural Snow


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
February 10th, 2002, Test #146, Run #1, Plate #5, Natural Snow


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
February 11th, 2002, Test #150, Run #2, Plate #4, Natural Snow


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
February 11th, 2002, Test #152, Run #3, Box #1, Natural Snow
Night
WS = 29.5 km/h
OAT = -5.6°C
Rate = 2.0 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Failure time = 52.4 minutes
-1
4
9
14
19
24
29
34
39
44
49
54
59
64
69
74
Time (minutes)

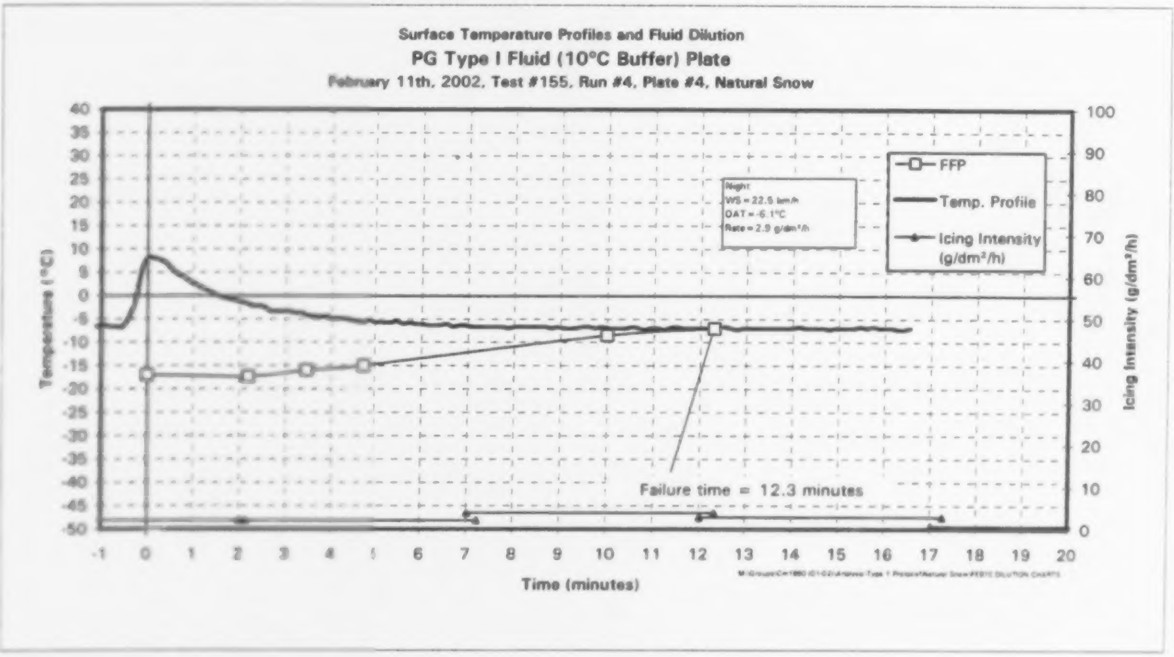

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
February 11th, 2002, Test #153, Run #3, Box #2, Natural Snow
Night
WS = 29.8 km/h
OAT = -5.6°C
Rate = 2.0 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Failure time = 49 minutes
-1
4
9
14
19
24
29
34
39
44
49
54
59
64
69
74
Time (minutes)



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

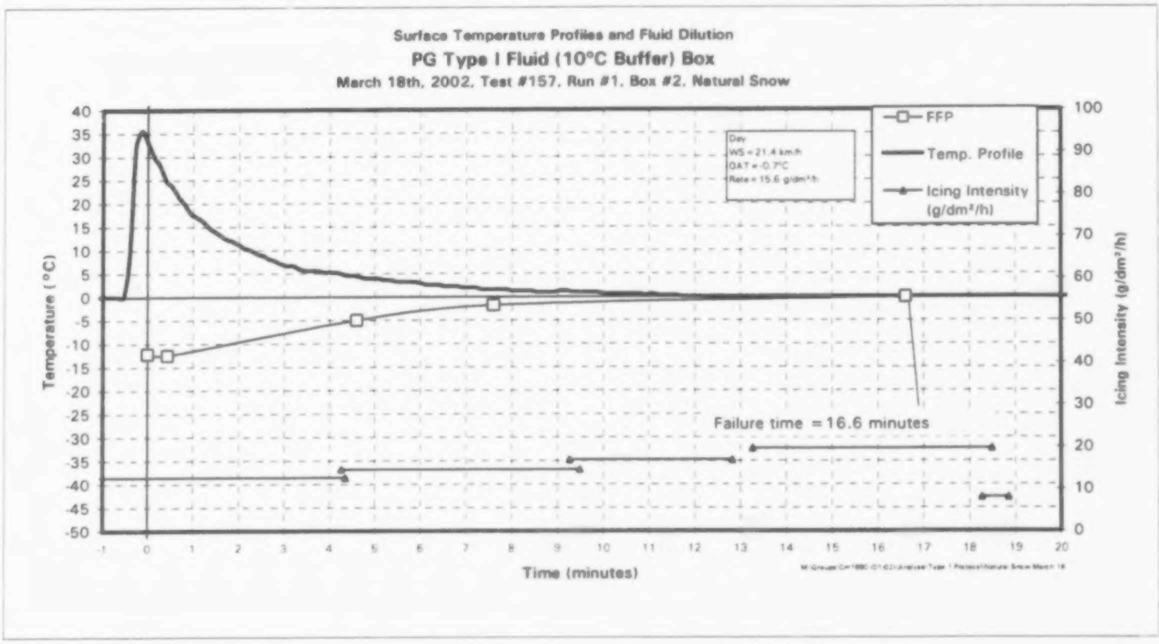
February 11th, 2002, Test #154, Run #3, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

February 11th, 2002, Test #155, Run #4, Plate #4, Natural Snow


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
March 18th, 2002, Test #157, Run #1, Box #2, Natural Snow
Day
WS = 21.4 km/h
OAT = -0.7°C
Rate = 15.6 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 16.6 minutes
Temperature (°C)
Icing Intensity (g/dm²/h)
Time (minutes)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
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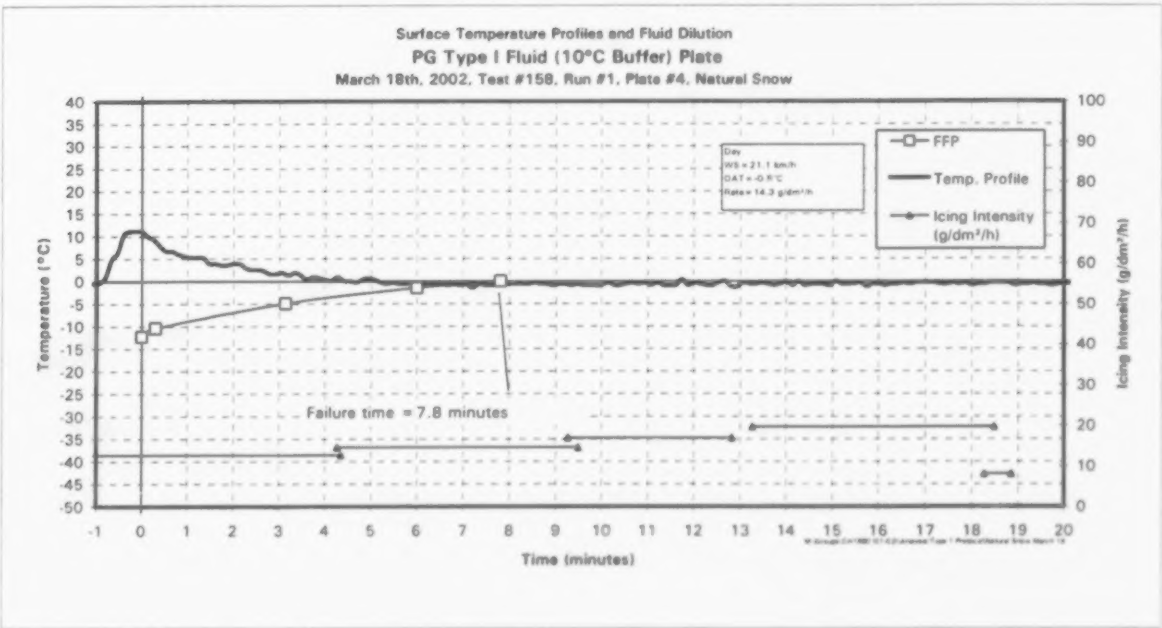
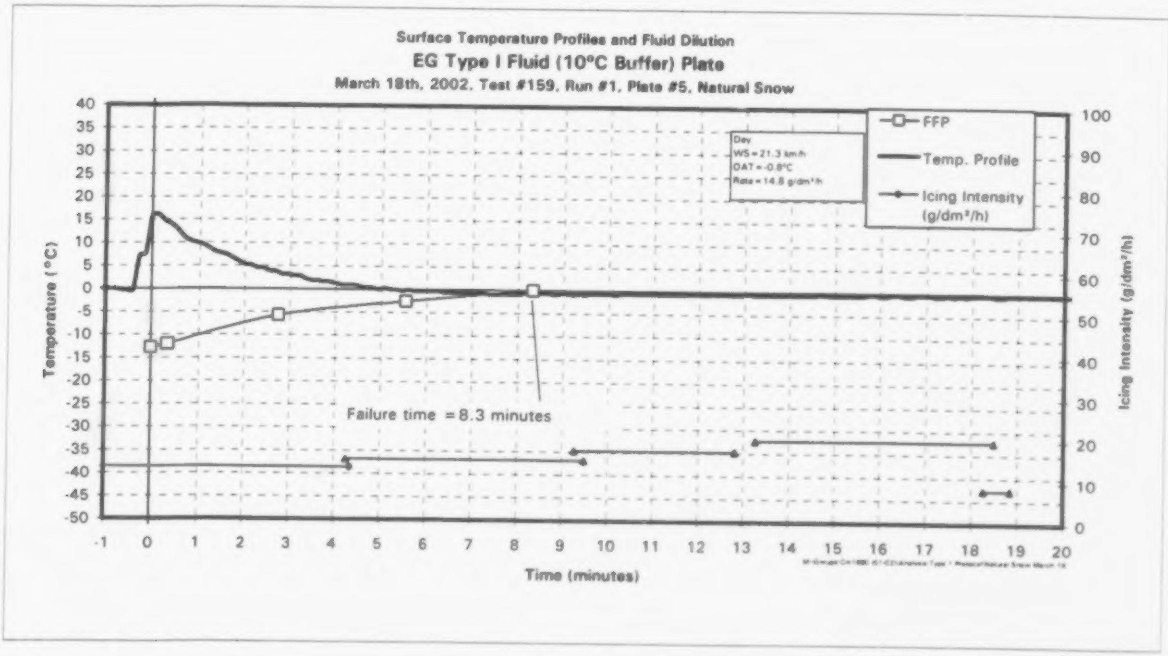
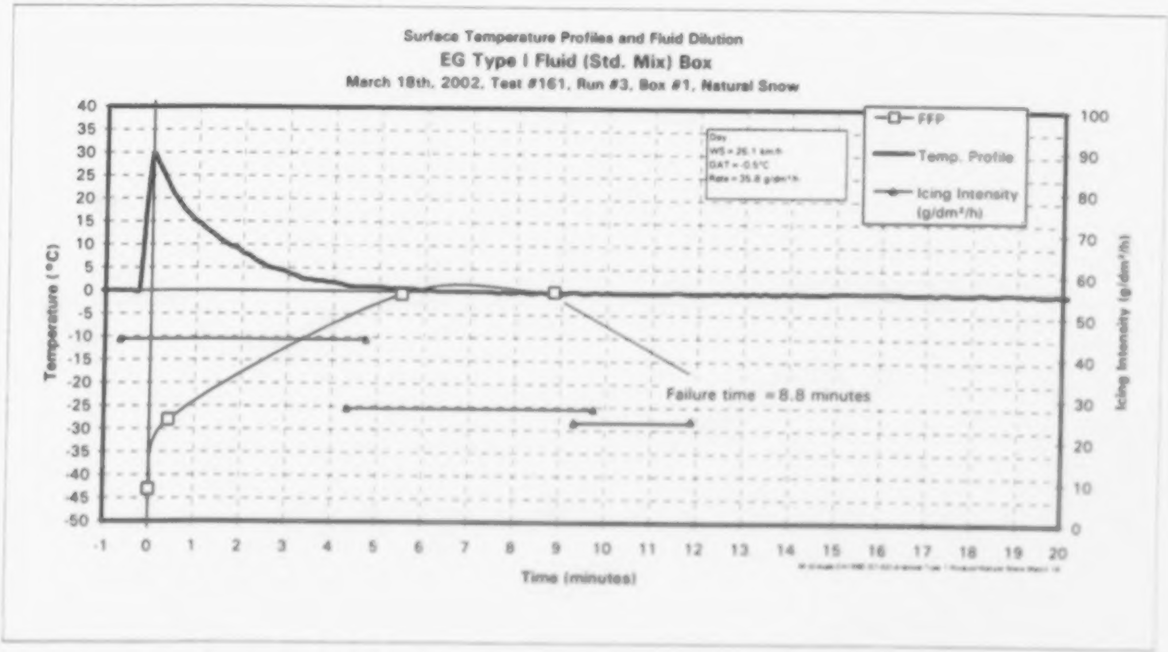
19
20

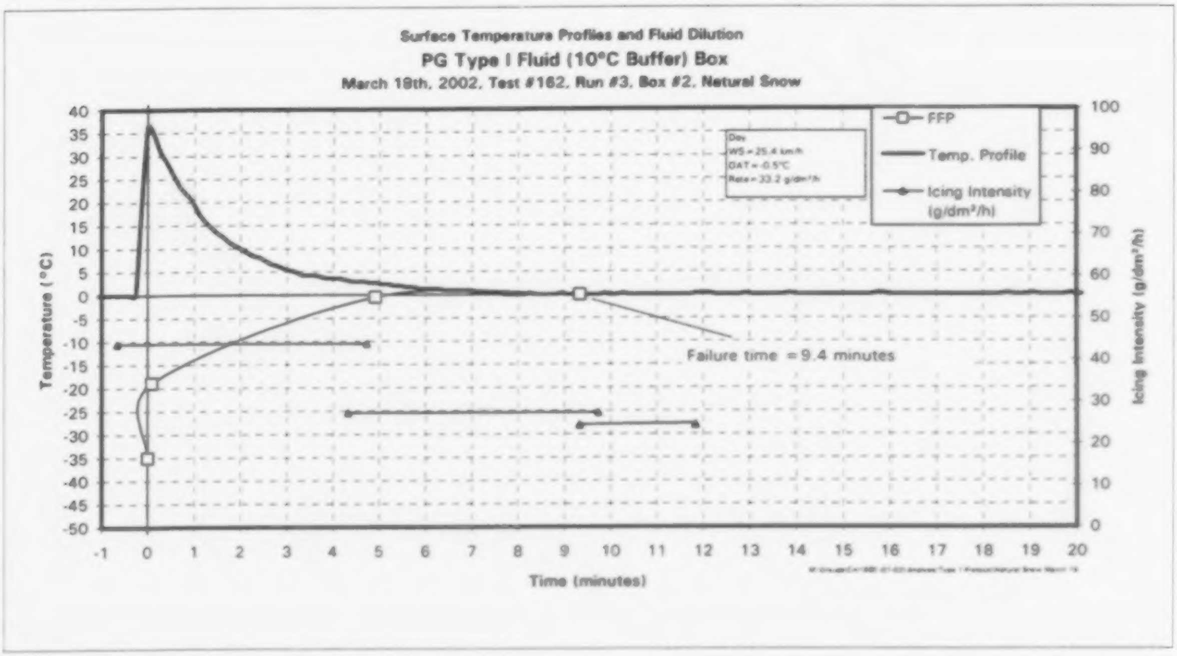

Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
March 18th, 2002, Test #158, Run #1, Plate #4, Natural Snow
Day
WS = 21.1 km/h
OAT = -0.8°C
Rate = 14.3 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 7.8 minutes
Temperature (°C)
Icing Intensity (g/dm²/h)
Time (minutes)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

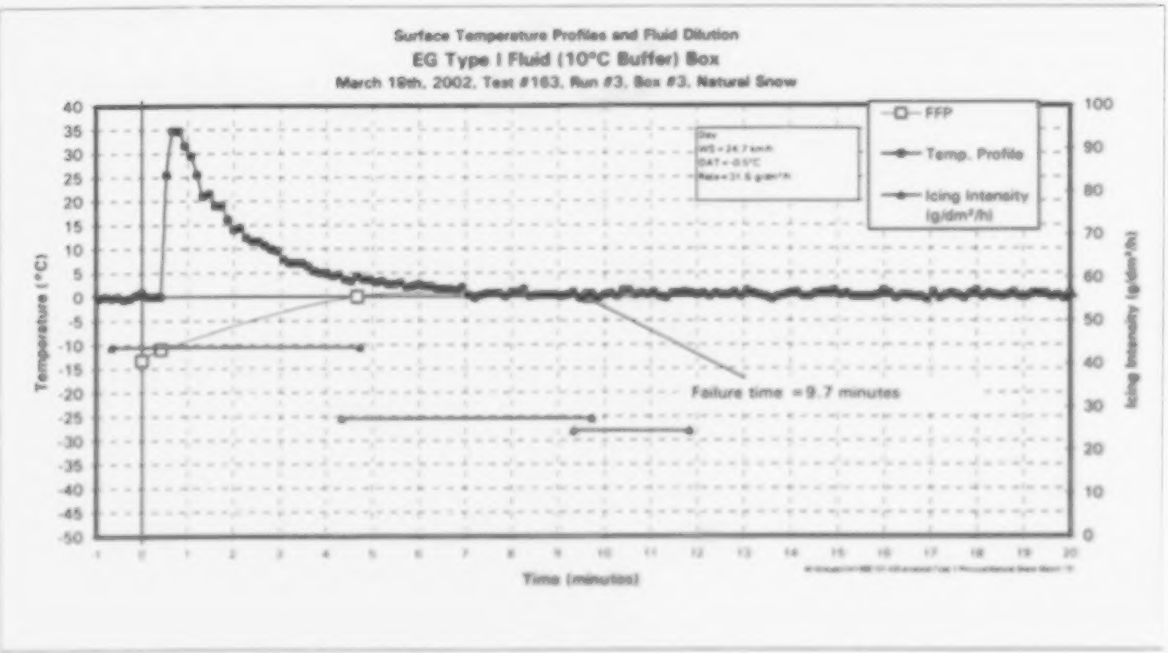


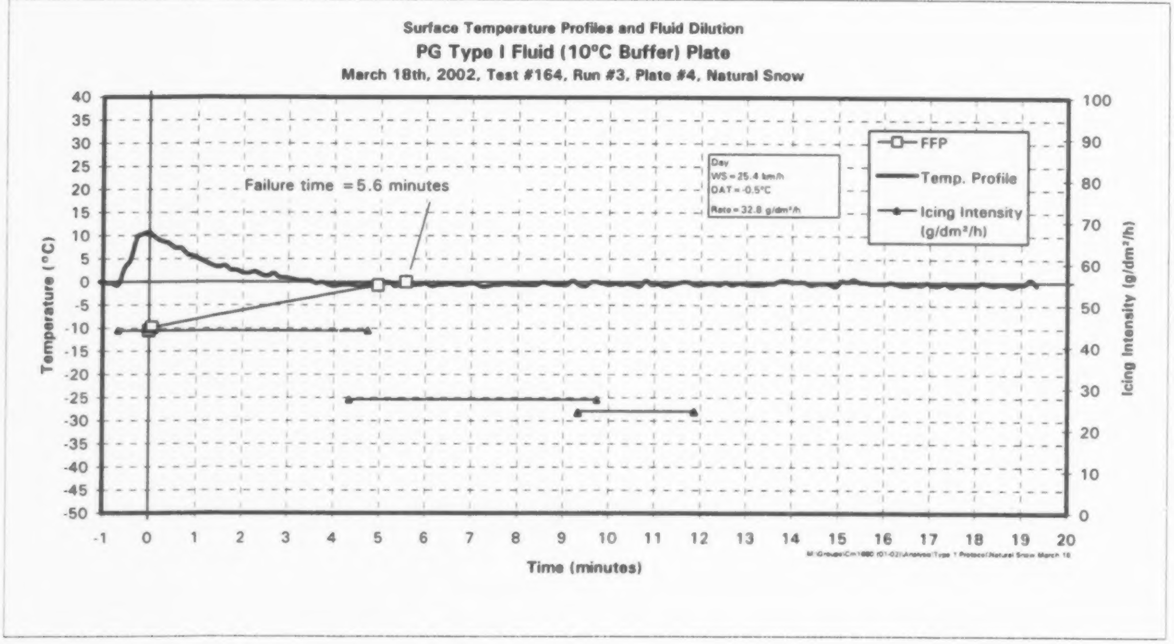
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
March 18th, 2002, Test #159, Run #1, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
March 18th, 2002, Test #161, Run #3, Box #1, Natural Snow


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
March 19th, 2002, Test #162, Run #3, Box #2, Natural Snow
Dev
WS = 25.4 km/h
OAT = -0.5°C
Rate = 33.2 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 9.4 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Time (minutes)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

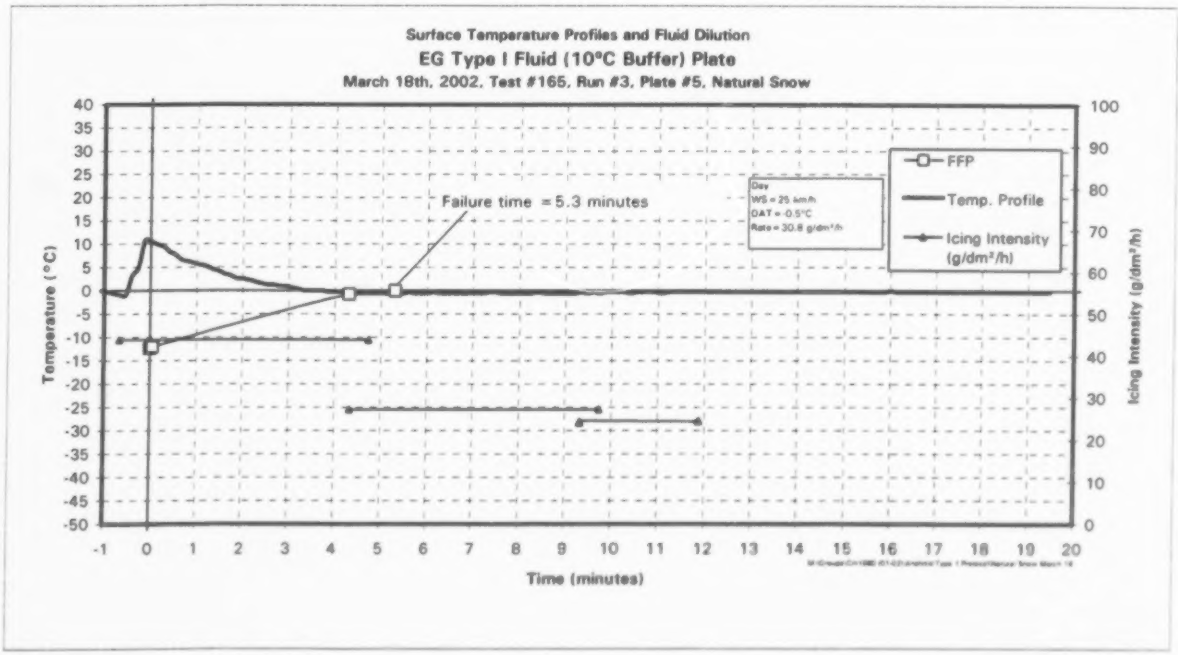

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
March 19th, 2002, Test #163, Run #3, Box #3, Natural Snow
Dev
WS = 24.7 km/h
OAT = -0.5°C
Rate = 31.5 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 9.7 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Time (minutes)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

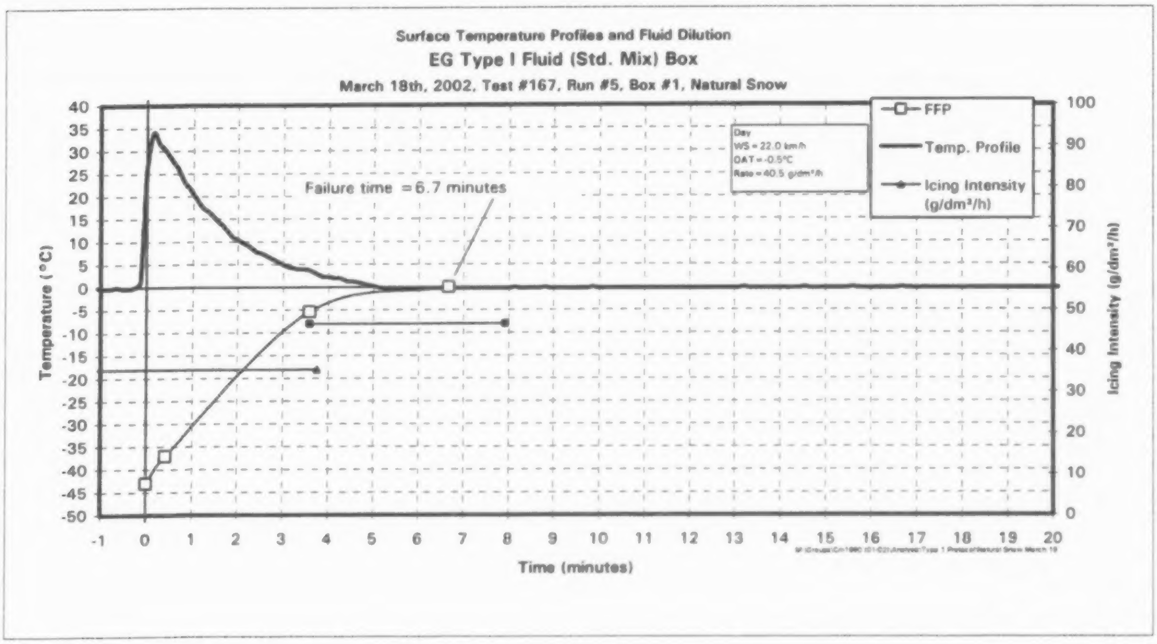
March 18th, 2002, Test #164, Run #3, Plate #4, Natural Snow

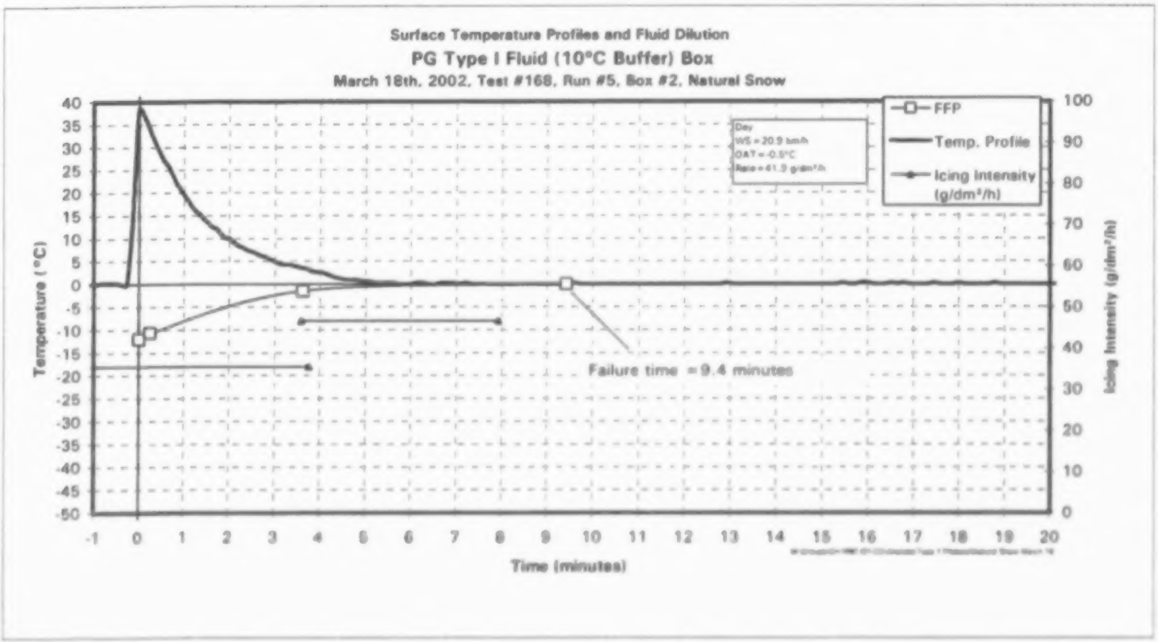


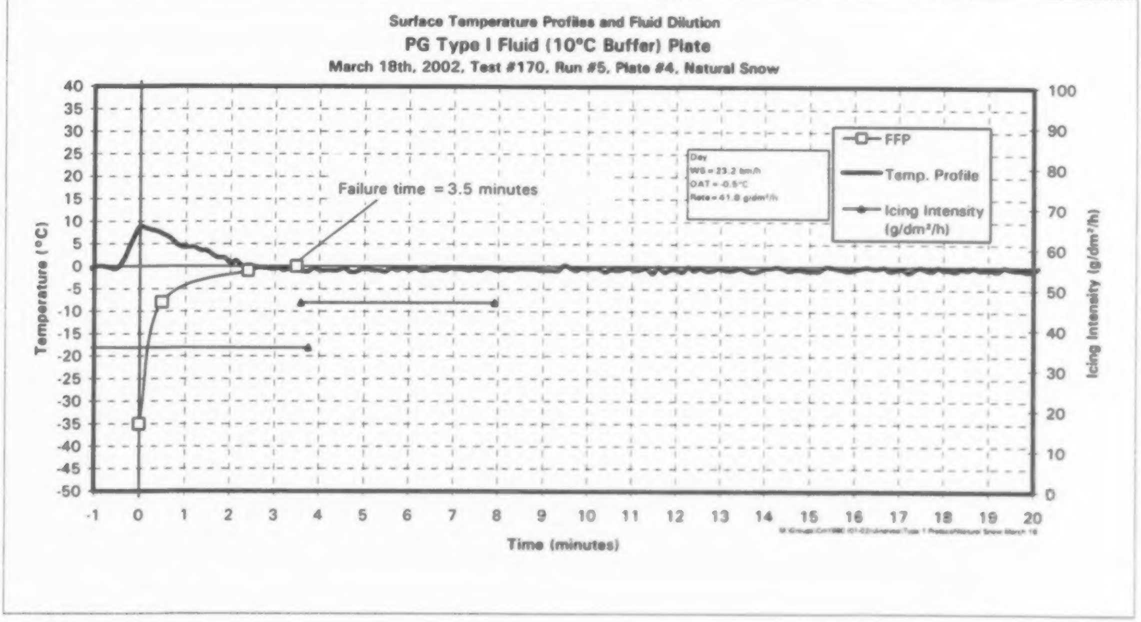
Surface Temperature Profiles and Fluid Dilution

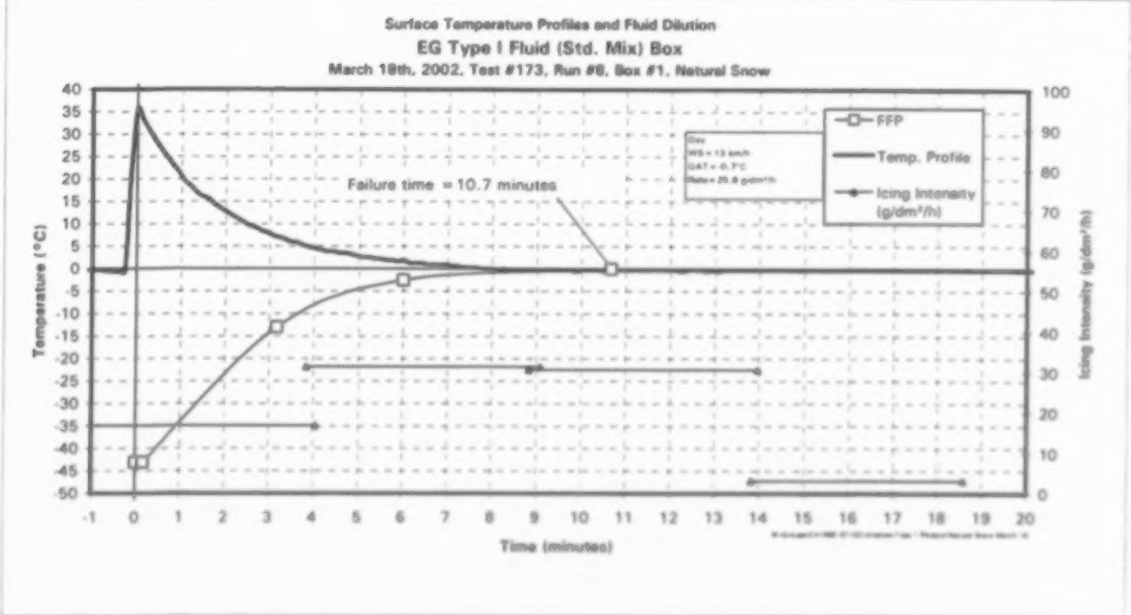
EG Type I Fluid (10°C Buffer) Plate

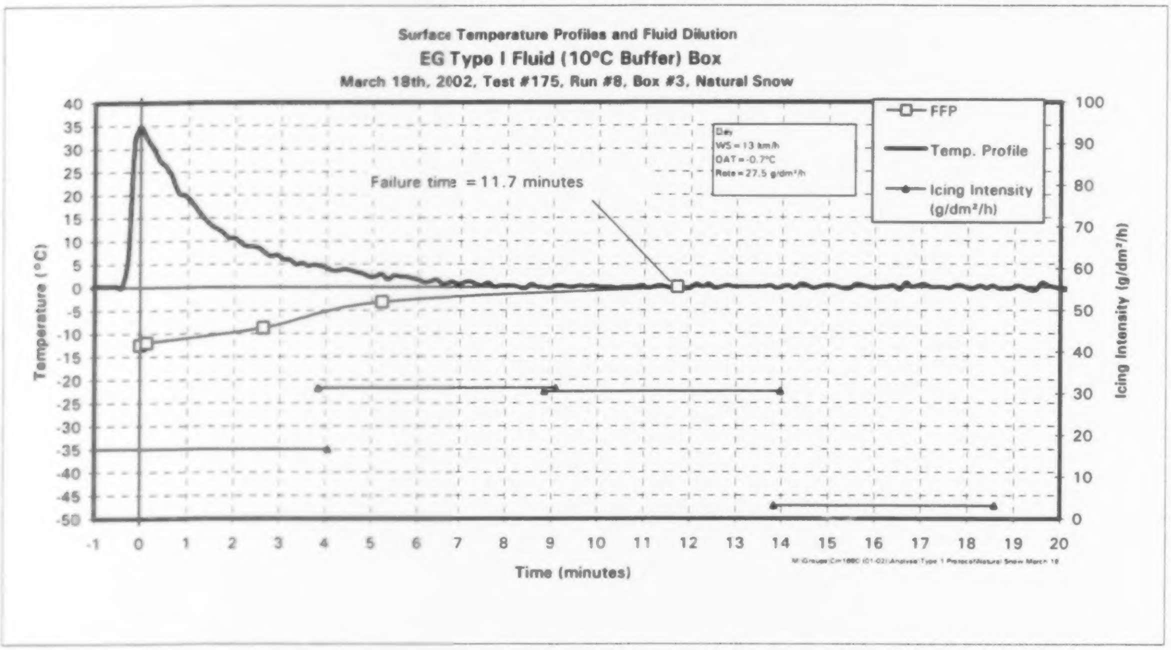
March 18th, 2002, Test #165, Run #3, Plate #5, Natural Snow

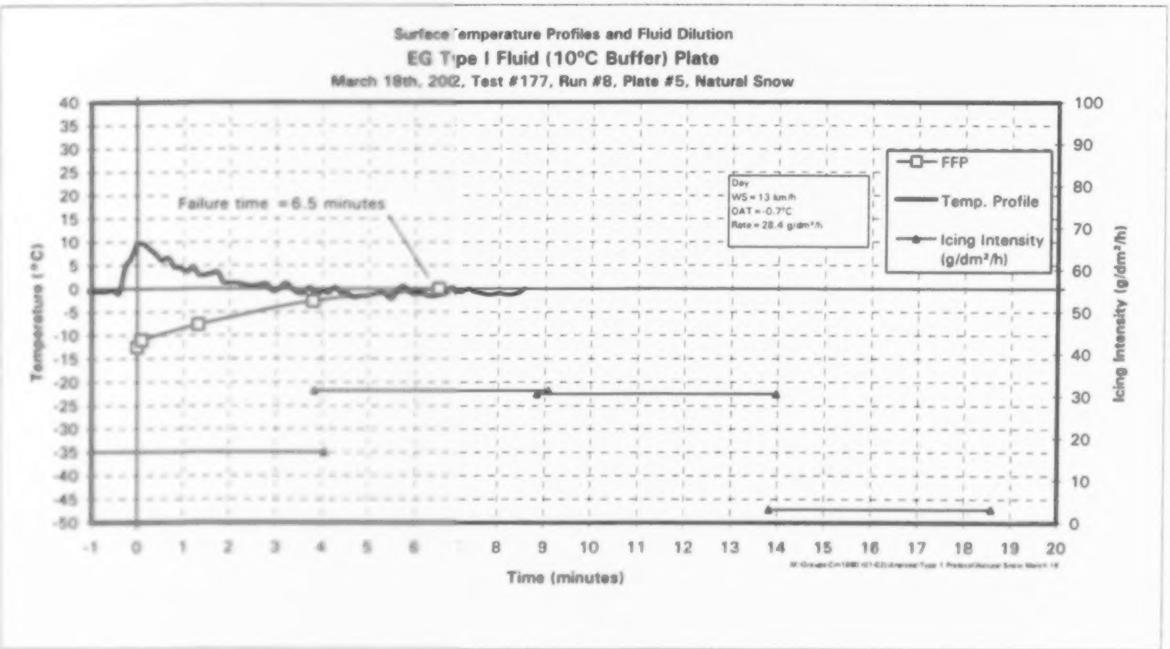

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
March 18th, 2002, Test #167, Run #5, Box #1, Natural Snow
Day
WS = 22.0 km/h
OAT = -0.5°C
Rate = 40.5 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 6.7 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time (minutes)


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
March 18th, 2002, Test #168, Run #5, Box #2, Natural Snow
Day
WS = 20.9 km/h
OAT = -0.5°C
Rate = 41.9 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
Failure time = 9.4 minutes
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time (minutes)


Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
March 18th, 2002, Test #170, Run #5, Plate #4, Natural Snow
Temperature (°C)
Icing Intensity (g/dm²/h)
Time (minutes)
Failure time = 3.5 minutes
Day
WS = 23.2 km/h
OAT = -0.5°C
Rate = 41.8 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
March 18th, 2002, Test #173, Run #8, Box #1, Natural Snow
Temperature (°C)
Icing Intensity (g/dm²/h)
Time (minutes)
Failure time = 10.7 minutes
Day
WS = 13 km/h
OAT = -0.7°C
Rate = 20.8 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
100
90
80
70
60
50
40
30
20
10
0
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

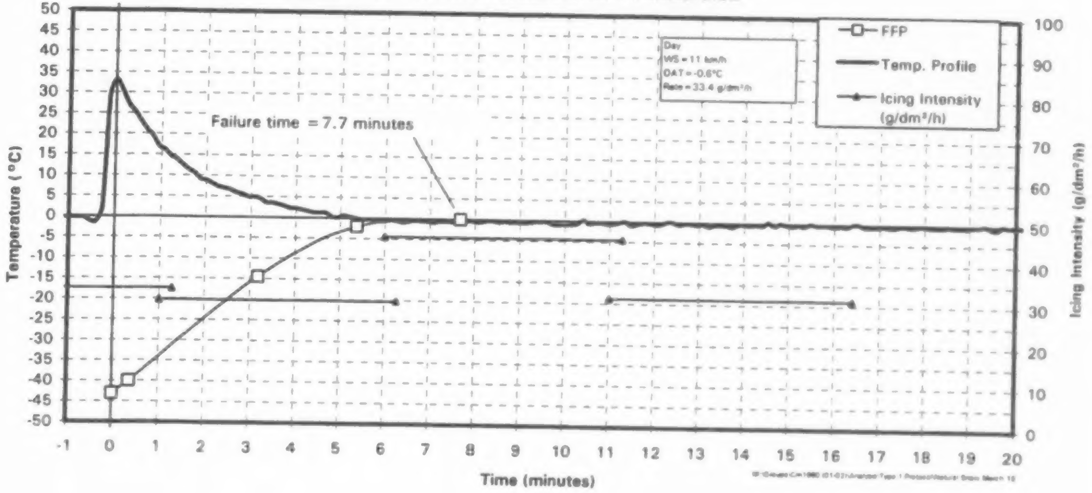

Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
March 18th, 2002, Test #175, Run #8, Box #3, Natural Snow


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
March 18th, 2002, Test #177, Run #8, Plate #5, Natural Snow

Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

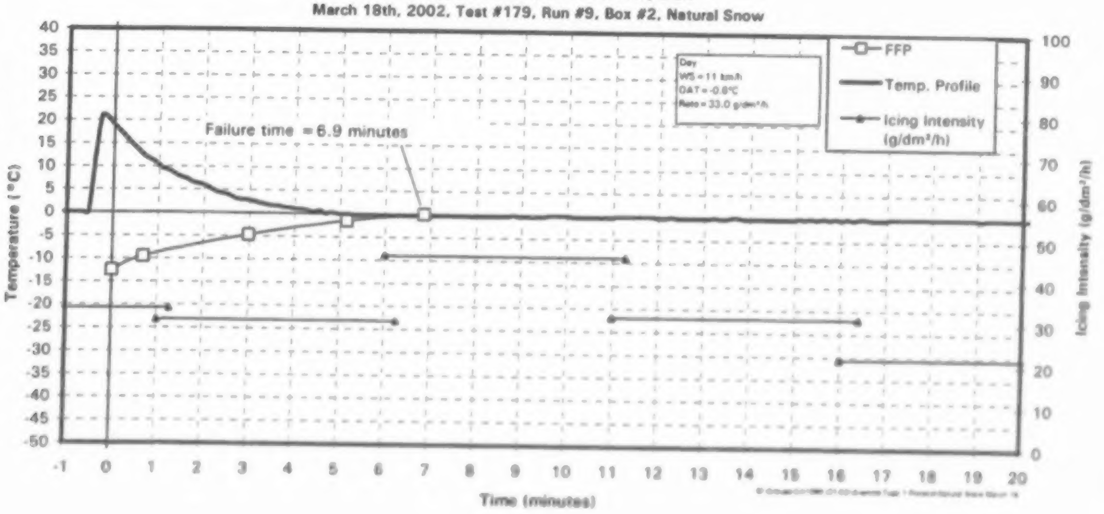
March 18th, 2002, Test #178, Run #9, Box #1, Natural Snow

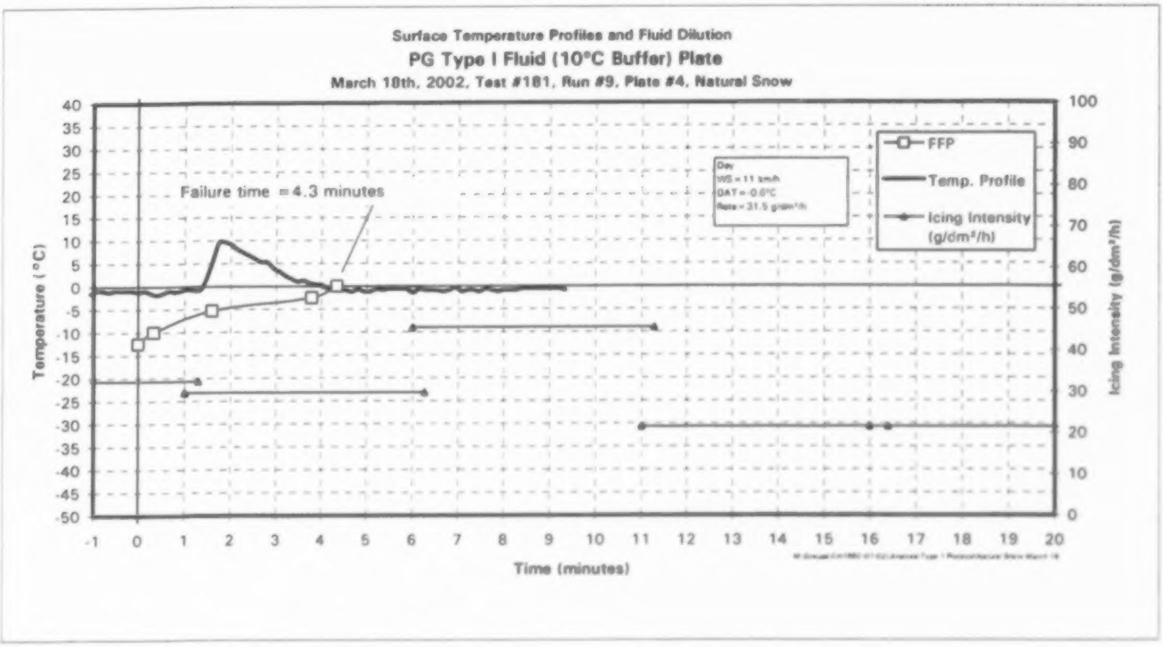


Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

March 18th, 2002, Test #179, Run #9, Box #2, Natural Snow

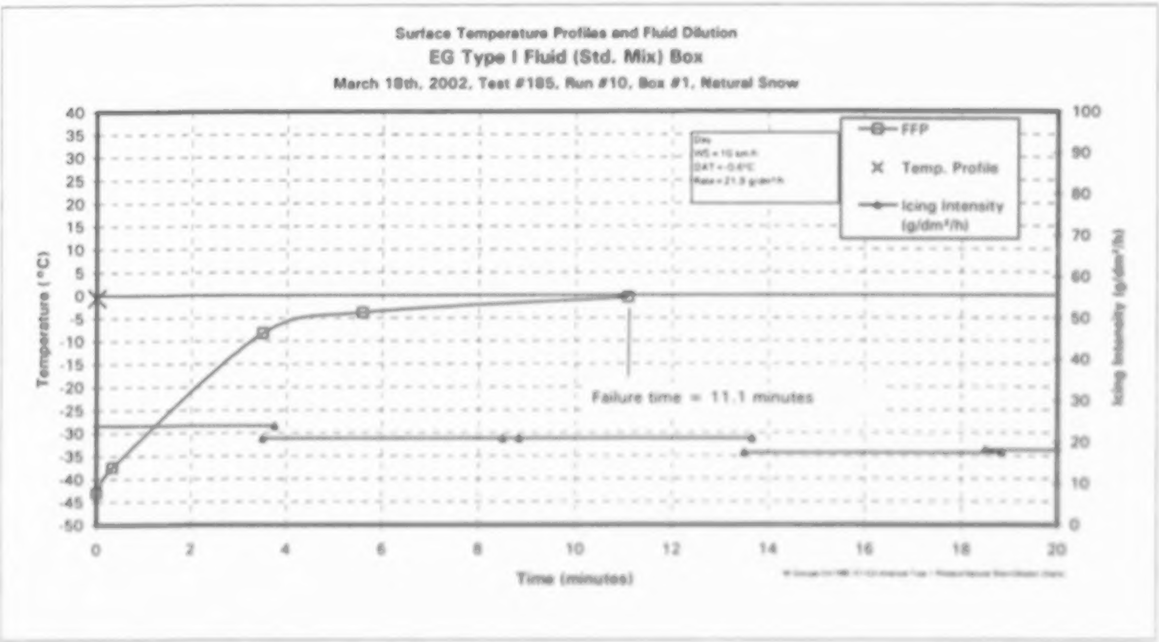




Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

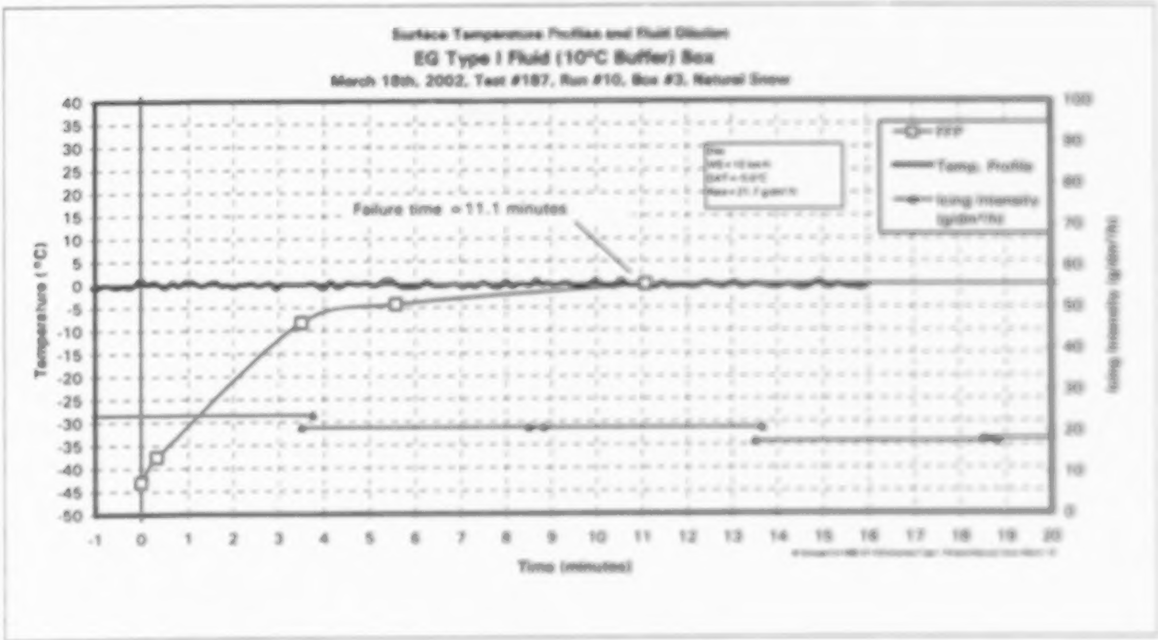
March 18th, 2002, Test #181, Run #9, Plate #4, Natural Snow



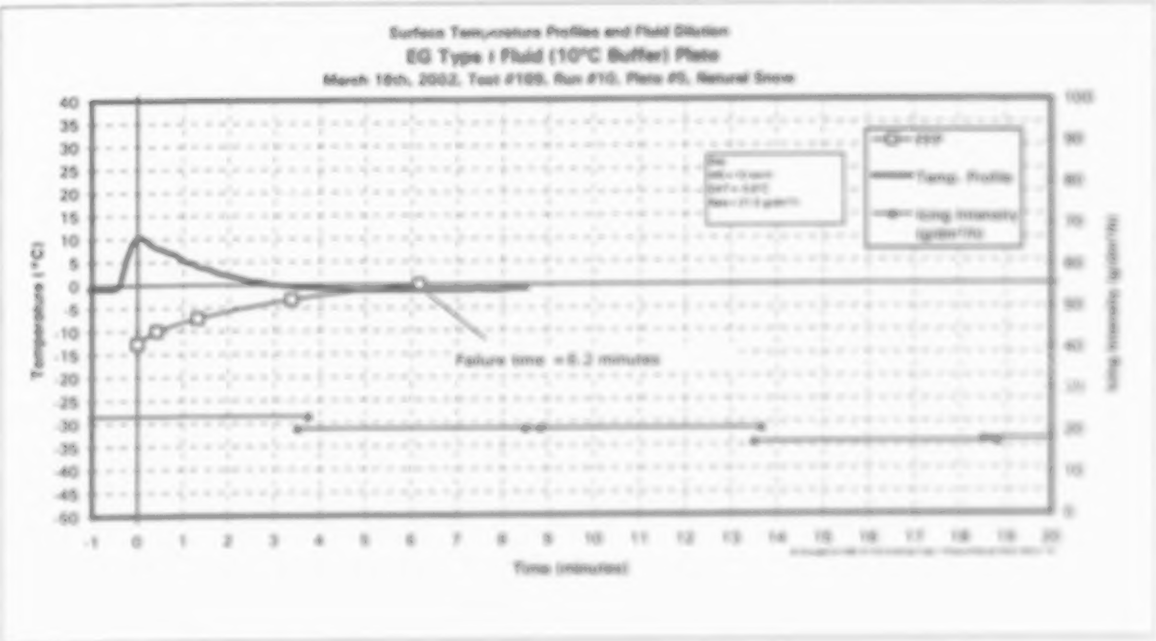
Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

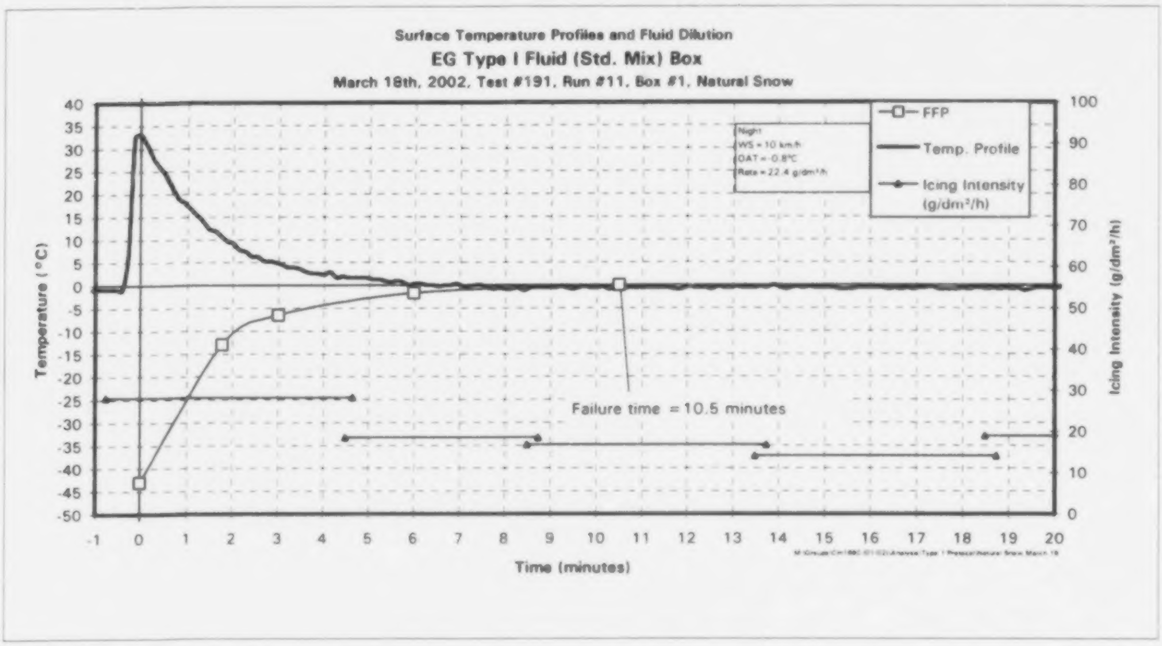
March 18th, 2002, Test #185, Run #10, Box #1, Natural Snow



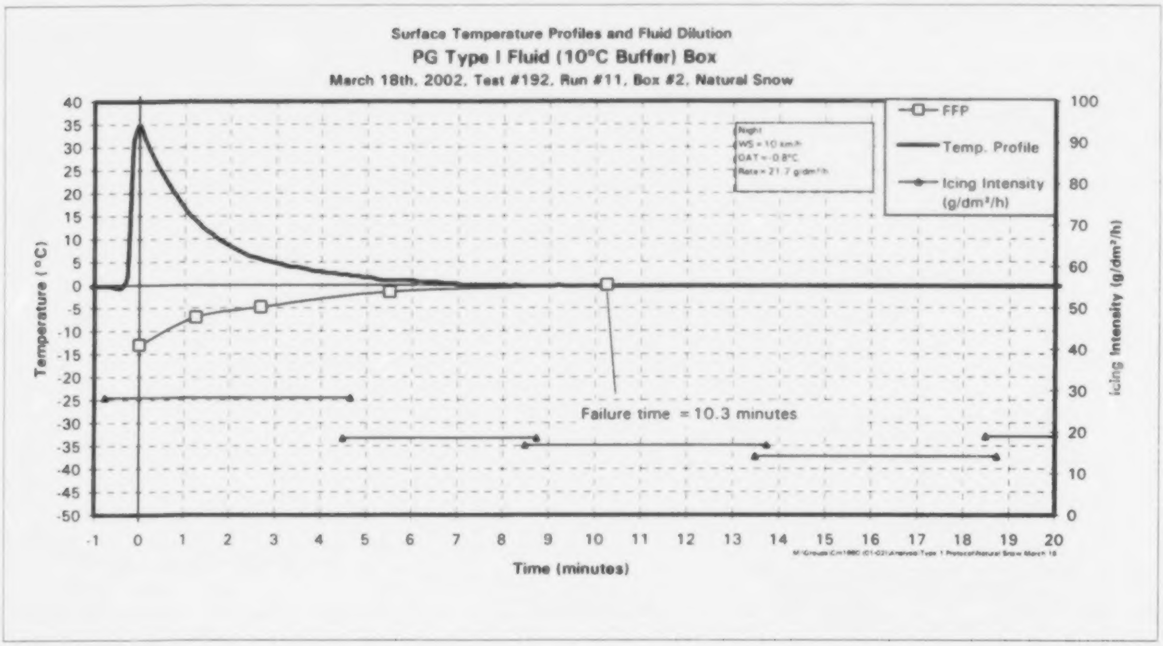
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
March 18th, 2002, Test #187, Run #10, Box #3, Natural Snow



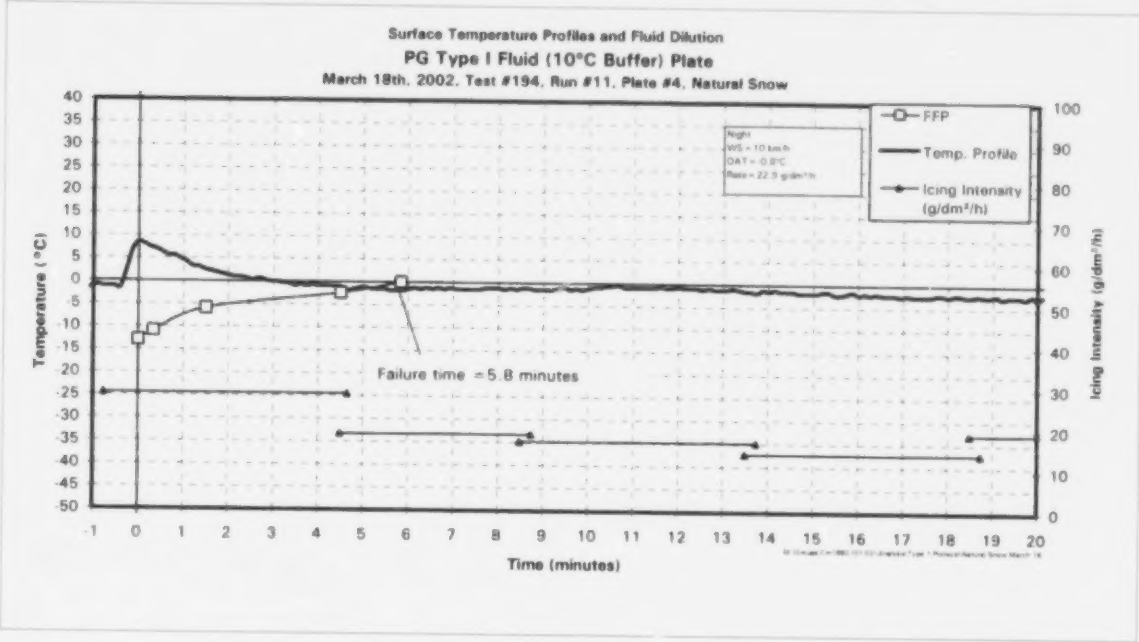
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
March 18th, 2002, Test #189, Run #10, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
March 18th, 2002, Test #191, Run #11, Box #1, Natural Snow



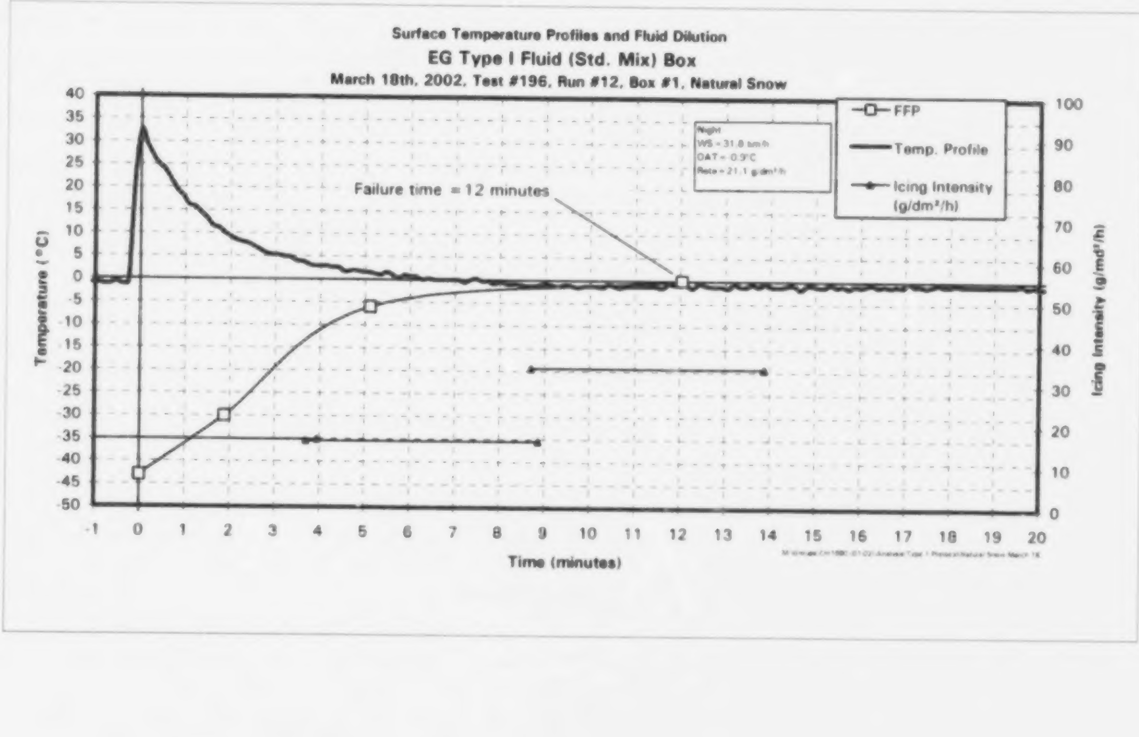
Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Box
March 18th, 2002, Test #192, Run #11, Box #2, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

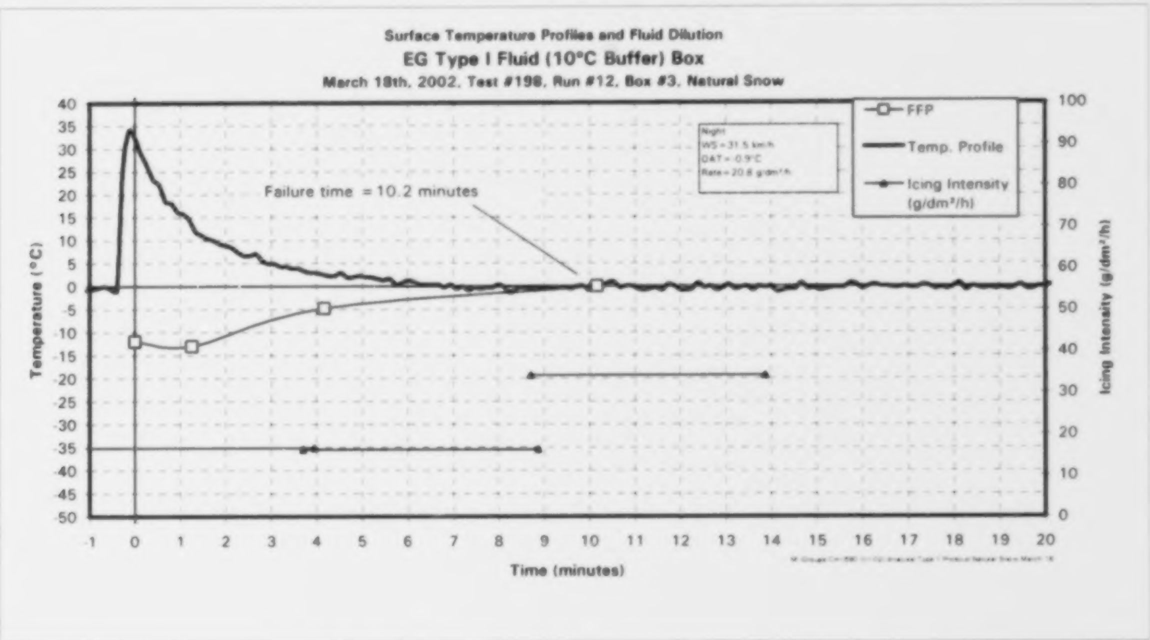
March 18th, 2002, Test #194, Run #11, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution

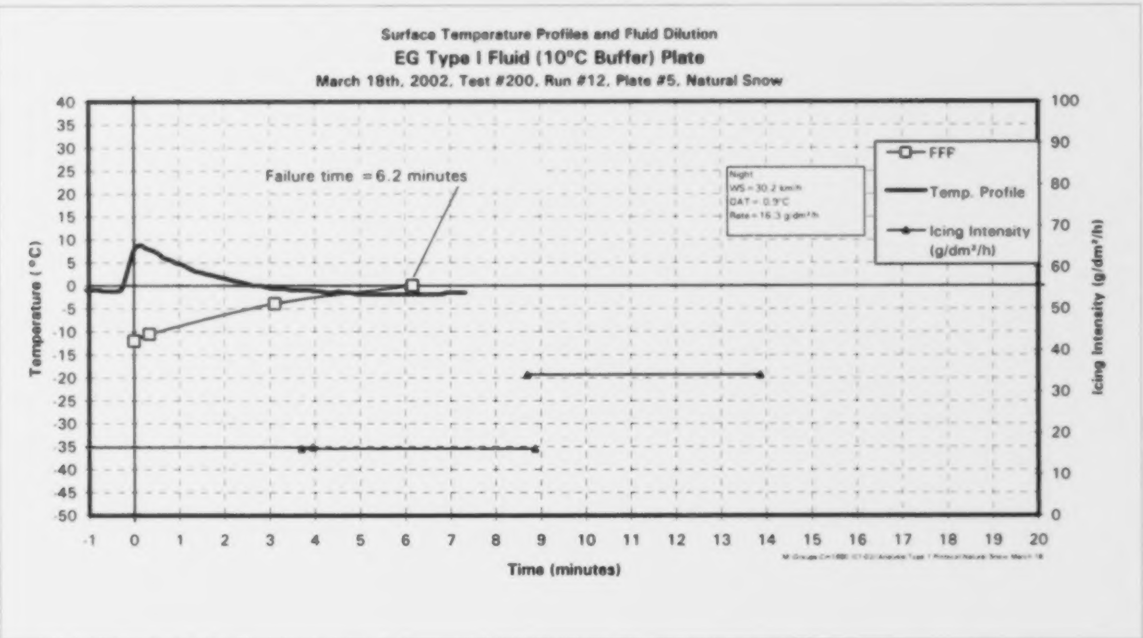
EG Type I Fluid (Std. Mix) Box

March 18th, 2002, Test #196, Run #12, Box #1, Natural Snow


Surface Temperature Profiles and Fluid Dilution

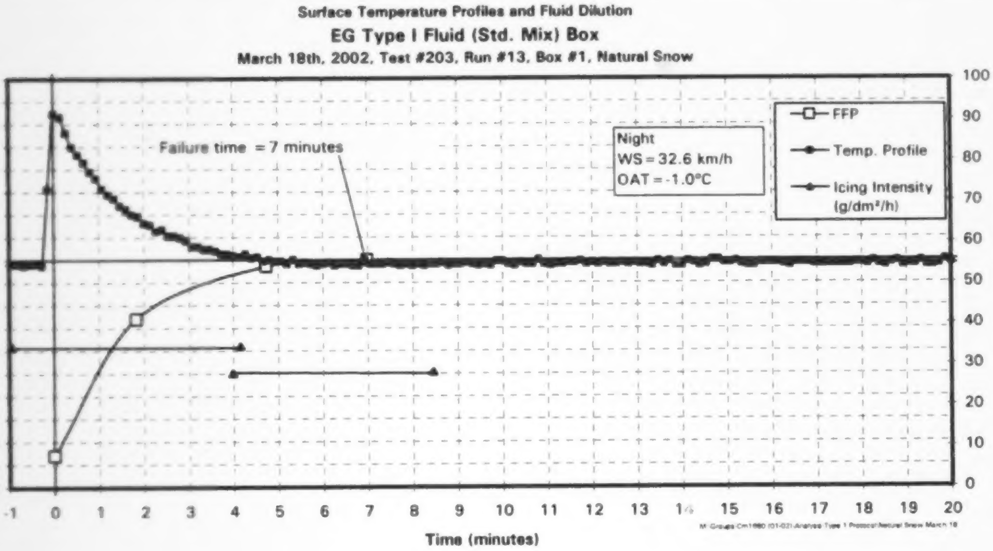
EG Type I Fluid (10°C Buffer) Box

March 18th, 2002, Test #198, Run #12, Box #3, Natural Snow


Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

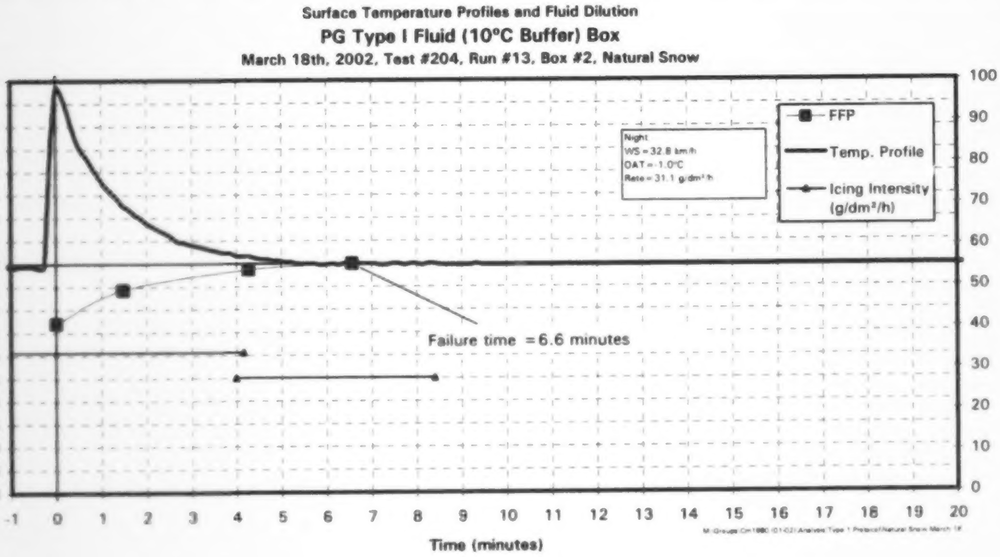
March 18th, 2002, Test #200, Run #12, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (Std. Mix) Box

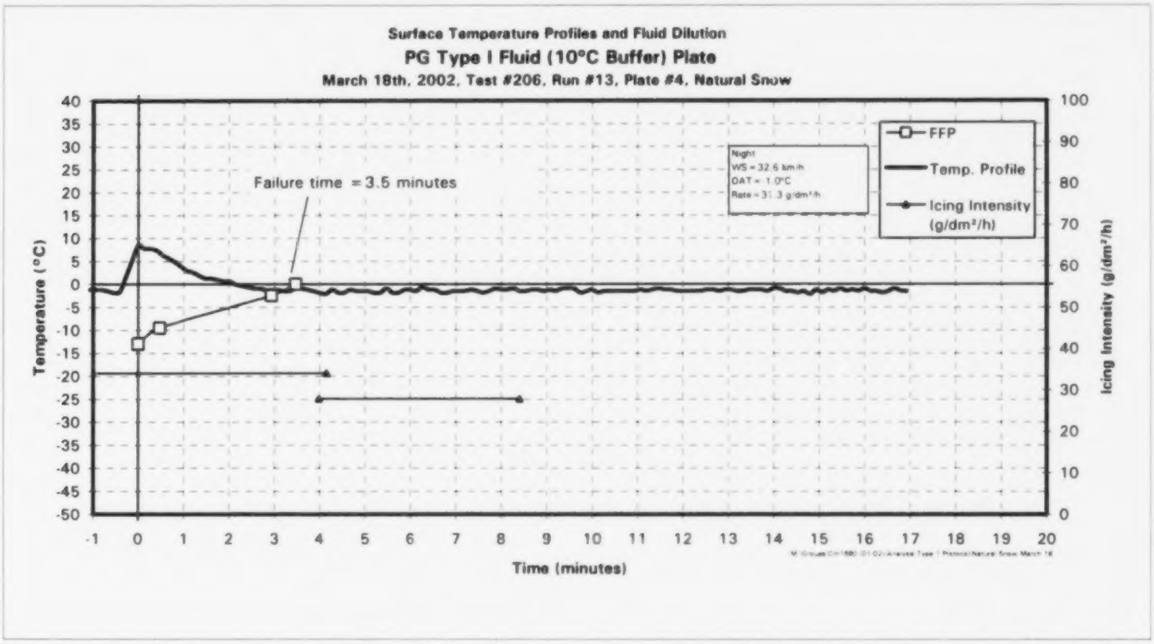
March 18th, 2002, Test #203, Run #13, Box #1, Natural Snow

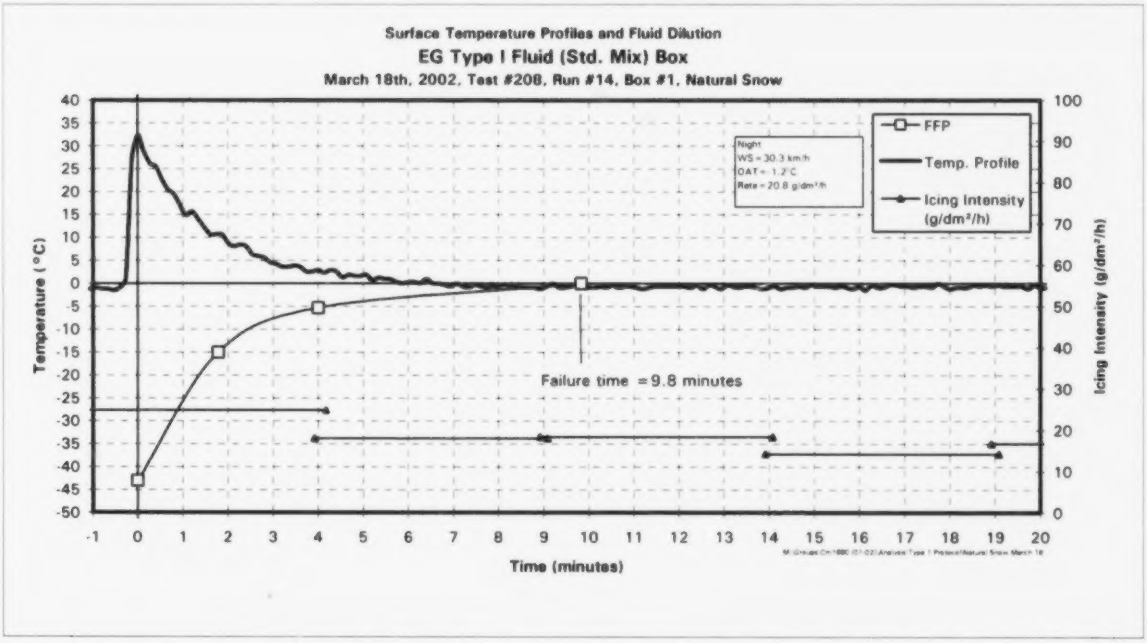


Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

March 18th, 2002, Test #204, Run #13, Box #2, Natural Snow

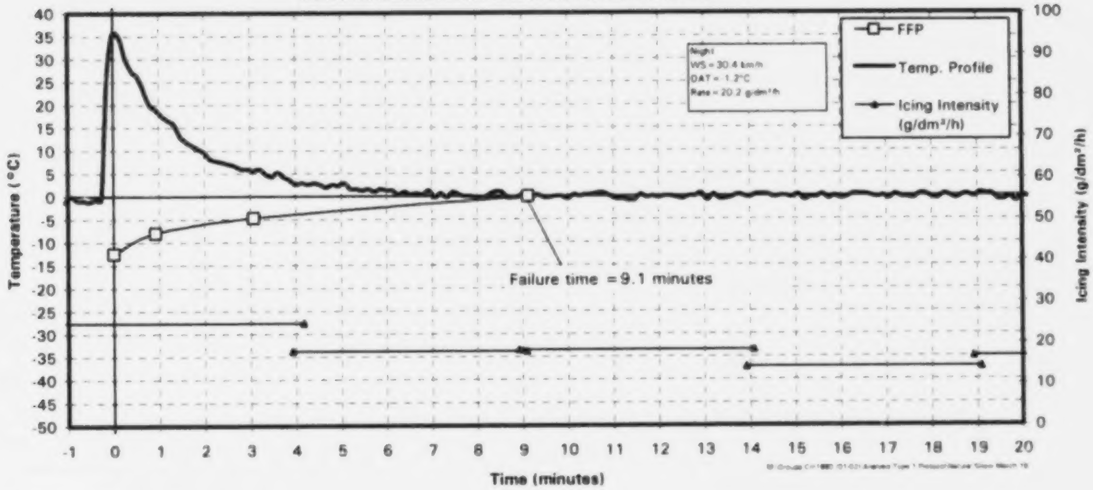

Surface Temperature Profiles and Fluid Dilution
PG Type I Fluid (10°C Buffer) Plate
March 18th, 2002, Test #206, Run #13, Plate #4, Natural Snow
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Time (minutes)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Failure time = 3.5 minutes
Night
WS = 32.6 km/h
OAT = -1.0°C
Rate = 31.3 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)


Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (Std. Mix) Box
March 18th, 2002, Test #208, Run #14, Box #1, Natural Snow
Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
Icing Intensity (g/dm²/h)
100
90
80
70
60
50
40
30
20
10
0
Time (minutes)
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Failure time = 9.8 minutes
Night
WS = 30.3 km/h
OAT = -1.2°C
Rate = 20.8 g/dm²/h
FFP
Temp. Profile
Icing Intensity (g/dm²/h)

Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Box

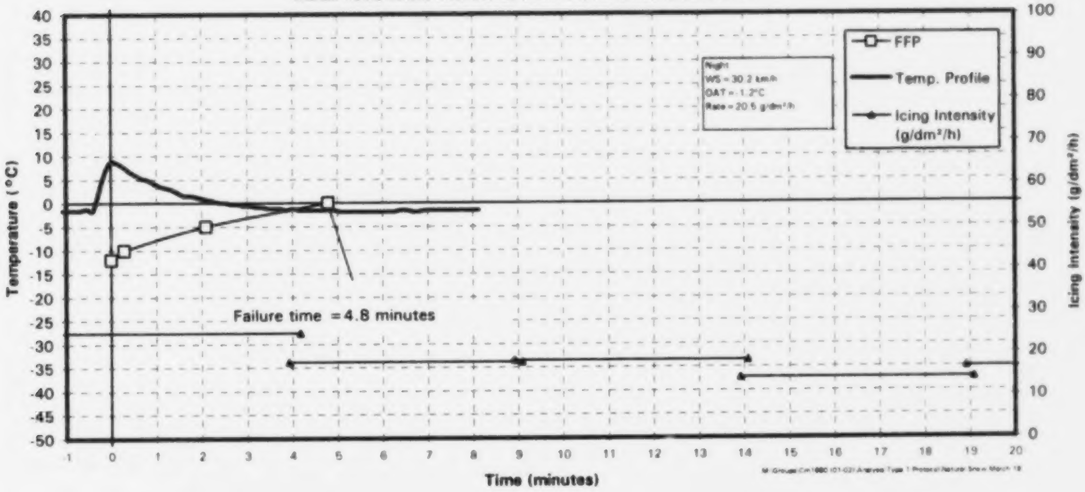
March 18th, 2002, Test #210, Run #14, Box #3, Natural Snow

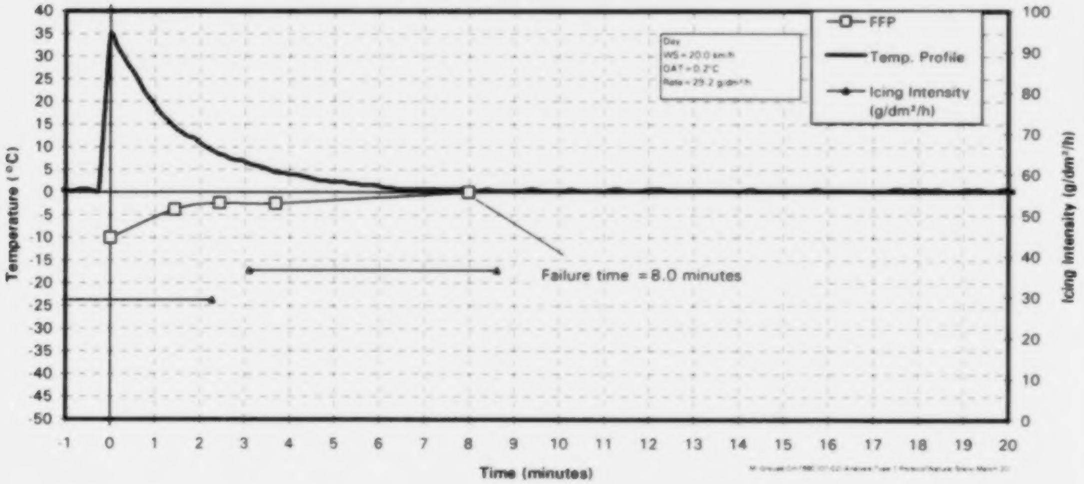


Surface Temperature Profiles and Fluid Dilution

EG Type I Fluid (10°C Buffer) Plate

March 18th, 2002, Test #212, Run #14, Plate #5, Natural Snow

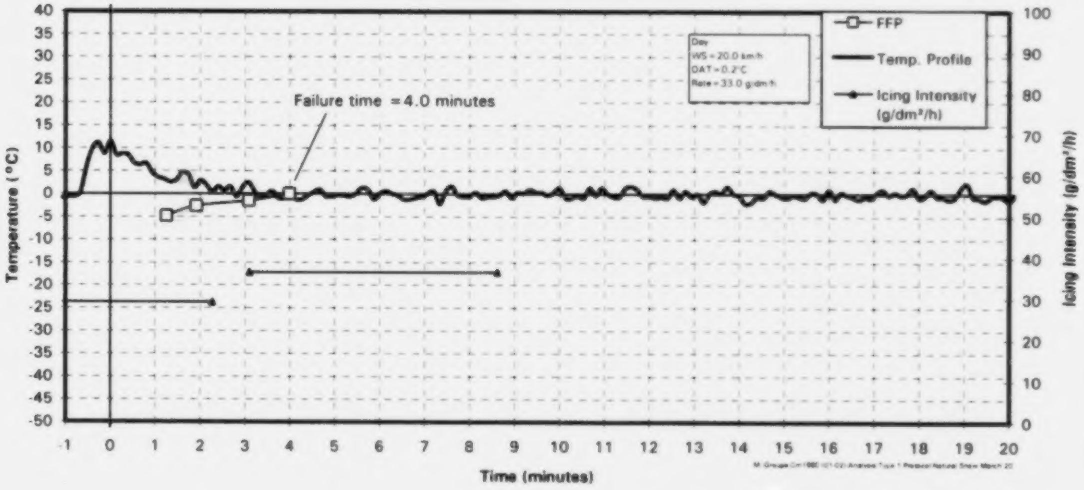




Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

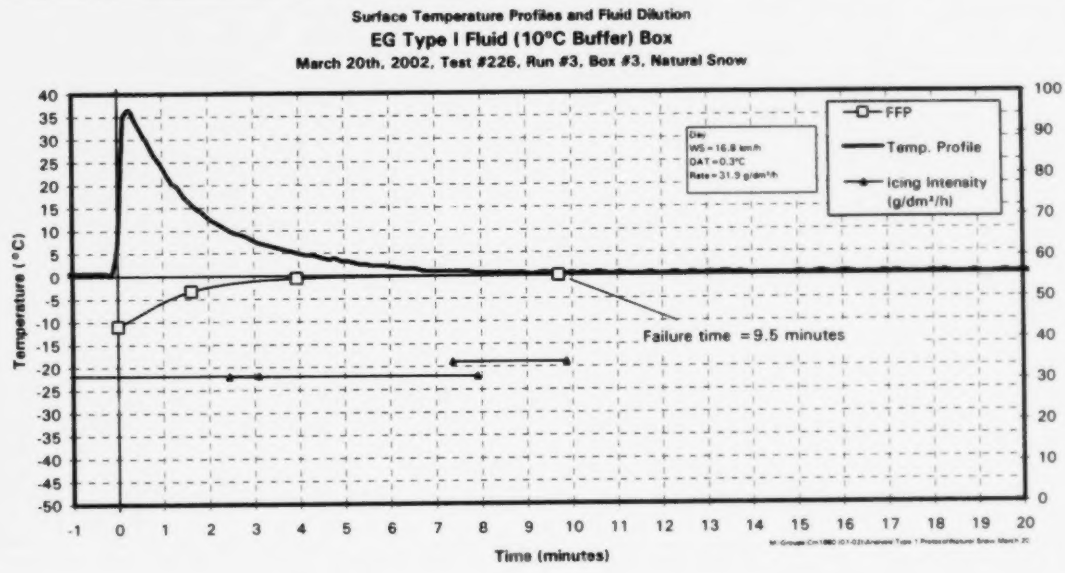
March 20th, 2002, Test #220, Run #2, Box #2, Natural Snow



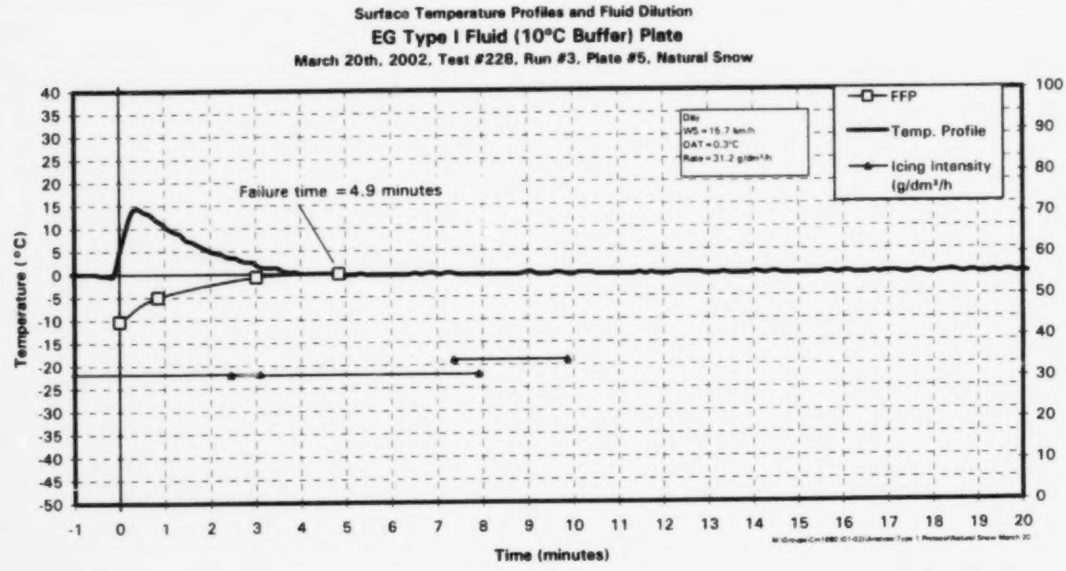
Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

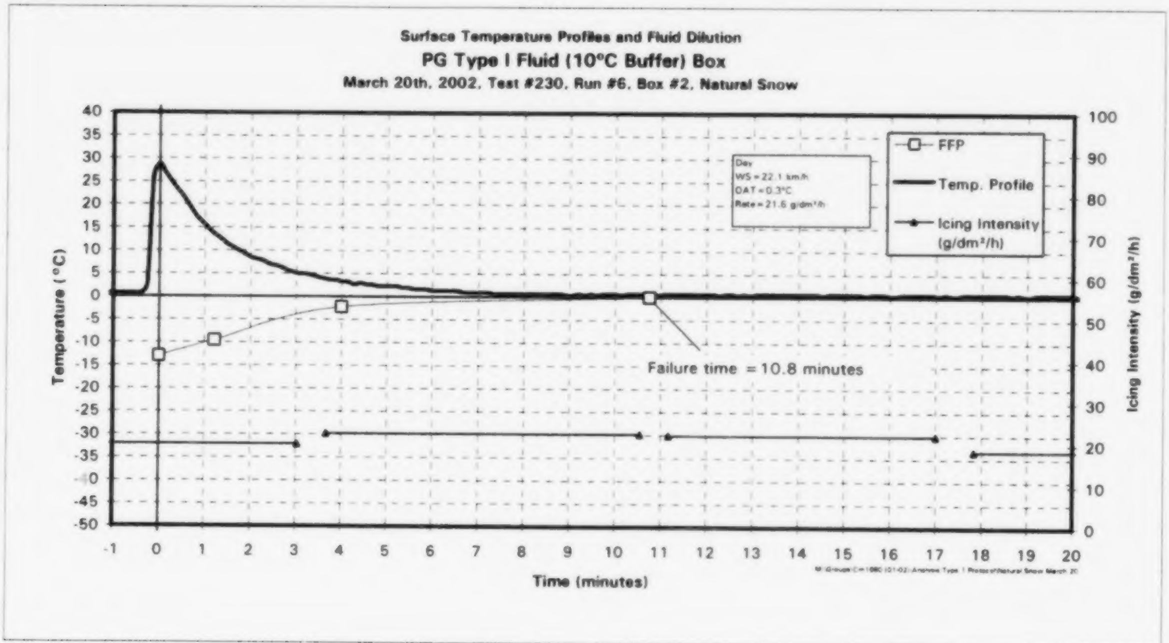
March 20th, 2002, Test #222, Run #2, Plate #4, Natural Snow



Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Box
March 20th, 2002, Test #226, Run #3, Box #3, Natural Snow



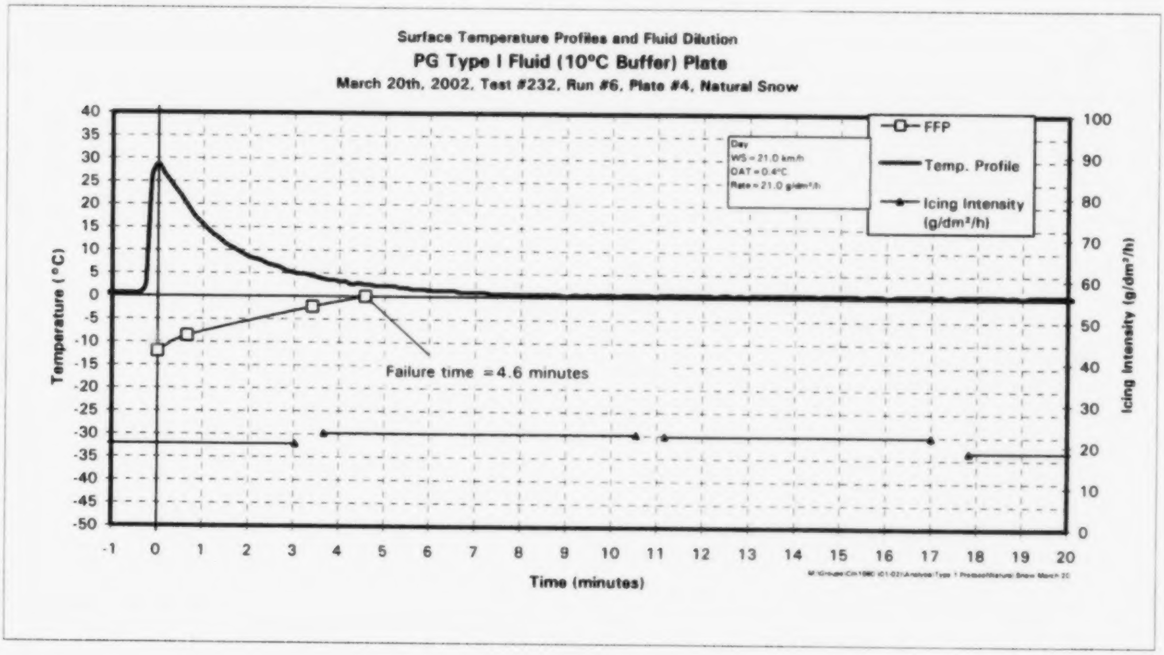
Surface Temperature Profiles and Fluid Dilution
EG Type I Fluid (10°C Buffer) Plate
March 20th, 2002, Test #228, Run #3, Plate #5, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Box

March 20th, 2002, Test #230, Run #6, Box #2, Natural Snow



Surface Temperature Profiles and Fluid Dilution

PG Type I Fluid (10°C Buffer) Plate

March 20th, 2002, Test #232, Run #6, Plate #4, Natural Snow

L

APPENDIX L

ANALYSIS OF THE CONFIDENCE LEVEL OF THE MEAN CURVE GENERATED BY REGRESSION

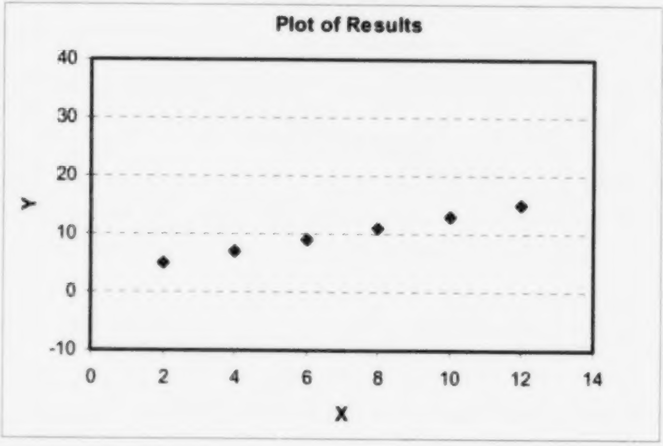
Analysis of the Confidence Level of the Mean Curve Generated by Regression

The following example is a graphical illustration of the confidence intervals around the best-fit curve generated by regression analysis.

EXAMPLE

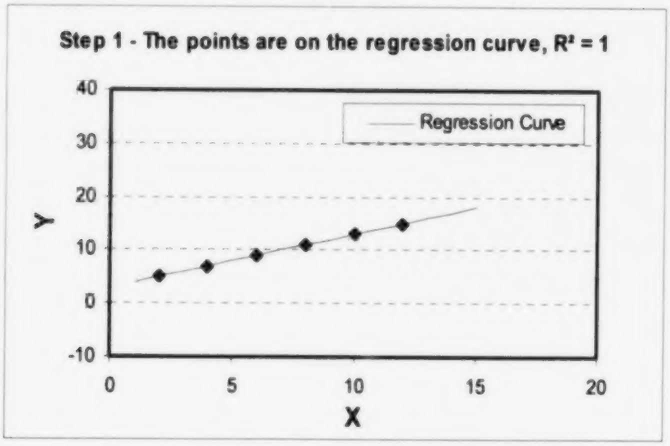
Let's assume we have two parameters (X and Y) relating to each other according to the following equation: $Y = X + 3$. For a small sample of X values (2, 4, 6, 8, 10, 12) Y values are calculated, and the results are presented in Figure A.

Figure A



The best-fit curve is calculated using regression analysis, and the output is illustrated in Figure B.

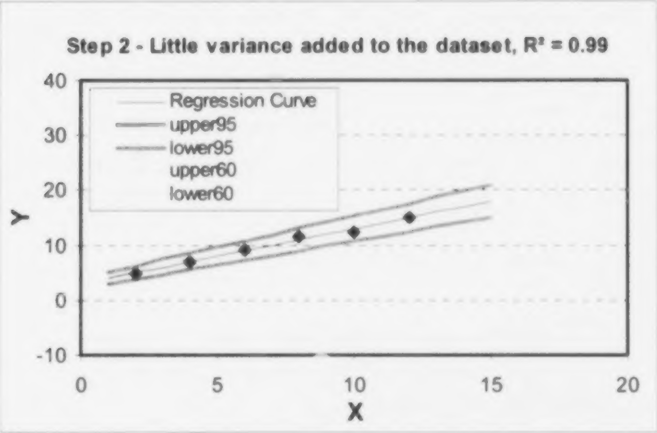
Figure B



Because there is a linear correlation between the parameters, all the values lie on the regression curve, which in this case is the slope defined be the equation $(Y = X + 3)$.

If little variance is introduced in the dataset by removing the linear correlation between the two parameters and slightly varying the Y values (while keeping the X values unchanged) the regression curve changes. Figure C shows the regression results, using the new parameters.

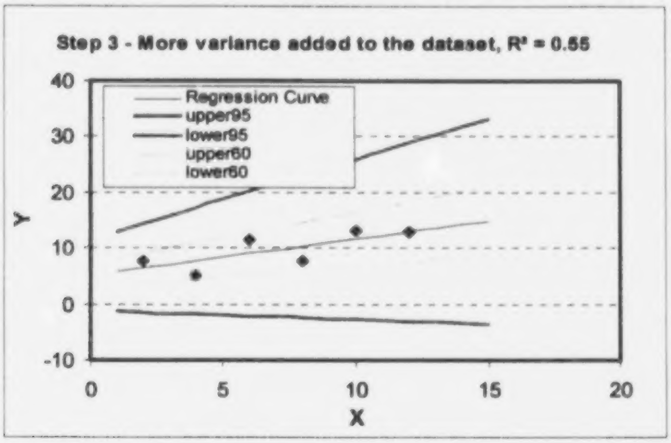
Figure C



The chart shows the confidence intervals for two confidence levels: 60% and 95%. These are confidence intervals for the population mean. A confidence level of 95% means that we are 95% confident that the range between upper95 and lower95 slopes, generated using the regression analysis, describes the true population mean. Or, in other words, we can be 95% sure that the confidence interval includes the true population mean. As expected the 60% confidence level falls within the 95% confidence level, because in this case we have only 60% confidence that the range includes the true population mean.

Increasing the degree of variance in the dataset by changing the Y values even more, the dataset spreads over a wider area in the chart. The best-fit curve calculated using the new values is presented in Figure D.

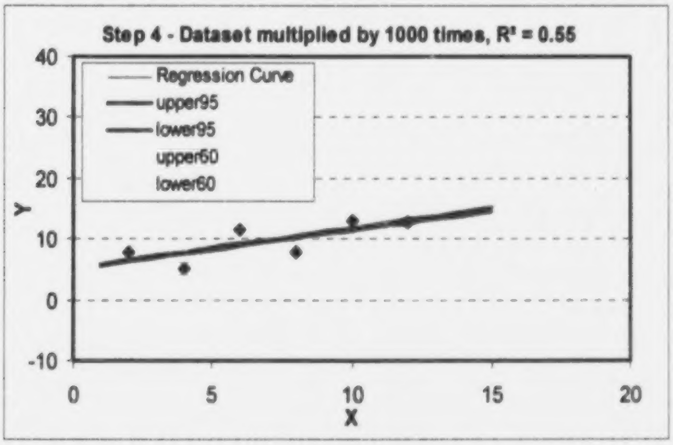
Figure D



As can be observed on the charts, while the data points spread out the confidence intervals become more open. If the distribution is broad the estimate (best-fit slope) is not very precise.

By multiplying each data point in Figure D a thousand times, without changing anything else, the regression analysis generates the results illustrated in Figure E.

Figure E



The output from the calculation shows that by multiplying the dataset, confidence intervals came very close, almost identical. As revealed previously, a very narrow confidence interval around the slope demonstrates a very precise estimate of the best-fit slope.